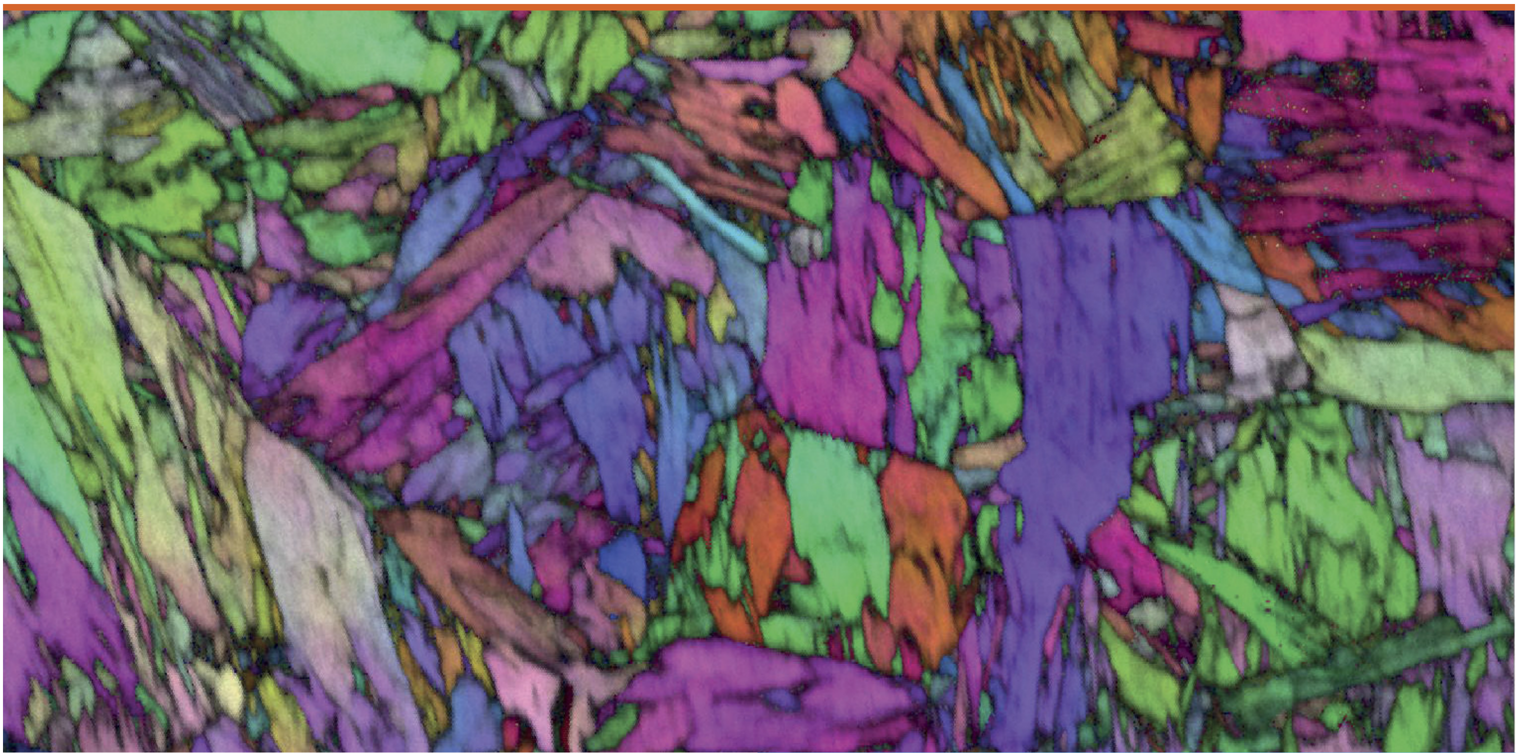
Annual Report 2010



DTU Mechanical Engineering
Department of Mechanical Engineering

Annual Report 2010

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Department of Mechanical Engineering
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Contents

Features

Introduction

The reorganized department of DTU Mechanical Engineering was created a few years ago and from the very beginning it has been an exciting and productive unit. 2010 has shown that the positive development continues and that the reorganization has been a success.

In January an international evaluation panel visited our department to carry out a research evaluation. The result of the evaluation made by the international panel was very satisfactory and showed that the department has several research groups in the absolute international top league and that research at the department has a very high standard.

At the end of the year there were nearly 250 employees in the department including 85 PhD-students. This is an increase of nearly 10% compared to the year before, and it reflects the increasing activity level in education and research.

An important objective for 2010 was the initiation of 33 new PhD projects as agreed upon with the management at DTU. Totally, 36 new PhD projects were initiated fulfilling the objective with a considerable margin. The number of PhD projects initiated in a single year has never been higher and it indicates a considerable increase in research activities.

Another milestone was reached in 2010 when new contracts for research projects at the department exceeded DKK 100 mio. Four new centers funded by The Danish Council for Strategic Research (DSF) alone counts for 37 mio DKK. Projects are made in close co-operation with industrial partners which have a high priority at the department. An application for the prestigious ERC Starting Grant was also successful confirming that the next generation of researchers is on their way.

DTU Mechanical Engineering 2010

A new Nordic Master in Maritime Engineering was also a reality and it is a breakthrough in the co-operation between the partners in Nordic Five Tech which is an alliance between five Nordic Technical Universities, i.e. Chalmers University of Technology, Gøteborg, Sweden, KTH Royal Institute of Technology, Stockholm, Sweden, Aalto University (the former Helsinki University of Technology), Helsinki, Finland, Norwegian University of Science and Technology (NTNU), Trondheim, Norway and the Technical University of Denmark, Kgs. Lyngby, Denmark.

In this Annual report 2010 the most important results have been highlighted combined with an overview of the activities at the department. I hope that you will enjoy the reading.

Henrik Carlsen
Professor, Head of Department

Highlights 2010

Professor Ole Sigmund receives much-coveted award

In January The Villum Kann Rasmussens Årslegat til Teknisk og Naturvidenskabelig Forskning (The Villum Kann Rasmussen Annual Award for Technical and Scientific Research) for 2010, worth DKK 2,500,000, was granted to Professor Ole Sigmund, DTU Mechanical Engineering, for his outstanding and innovative research in topology optimization. Topology optimization is a method to save weight in mechanical constructions. The method is based on computer calculations. Holes are placed in the construction to make it as light as possible whilst simultaneously ensuring that the construction can withstand pressure, twisting, bending and other types of stress.

Professor Sigmund's main research area is within the enhancement of composite materials, antennas, optics and the development of micro-robots for many practical and scientific purposes.

His achievements in topology optimization have resulted in numerous advances in many industries. He has been heading the development of the complex calculations and the software that is used today by major companies such as Airbus and Audi.

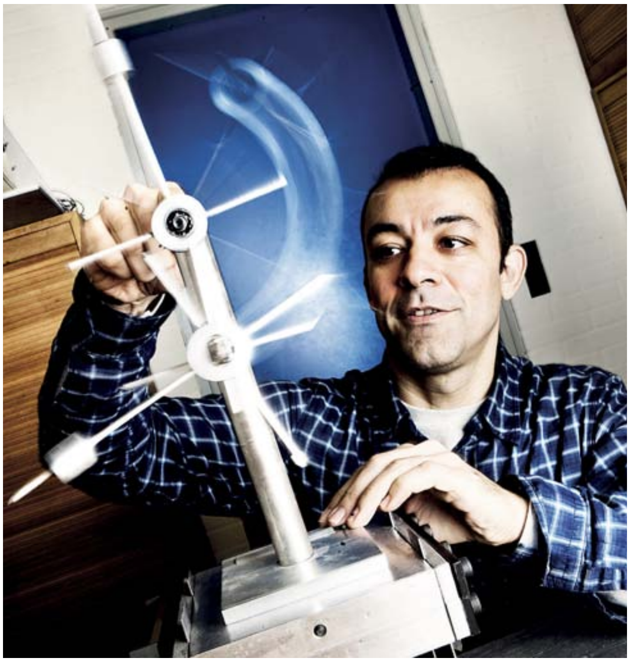
The M-award goes to 2 students at DTU Mechanical Engineering

In February Maskinteknisk Selskabs (the Society of Mechanical Engineering) award for the best final projects in mechanical engineering went to Jesper Lund Madsen and Uffe Bihlet. Both projects were undertaken at Materials and Surface Engineering, a section of DTU Mechanical Engineering. Professor Marcel Somers was main supervisor and postdoc Kristian Vinther Dahl was daily supervisor.

Jesper Lund Madsen received his award for his project about the use of an advanced microstructural model to estimate metal temperature in nickel-base alloy. This alloy is, among other things, used in the high-temperature part of gas turbines. Normally, it is necessary to do destructive test methods in order to see the microstructure and it is only possible to look at one alloy at a time. But Jesper Lund Madsen has been working with a universal model that can predict the disintegration of the microstructure.

Uffe Bihlet carried out the other project in close collaboration with MAN Diesel. For competitive reasons, its details cannot be revealed at this stage, but the overall idea is to develop a new material for valve stem seats in MAN Diesel's two-stroke engines in order to remove traditional corrosion problems.

Uffe Bihlet, Christian Vinther Dahl and Jesper Lund Madsen.



Research scientist receives Statoil Award 2010
Ilmar Santos, Associate Professor, dr. techn., at DTU Mechanical Engineering, received the Statoil Award 2010 in March. The DKK 100,000 Award was granted to the Brazilian-born researcher in recognition of his extensive research in mechatronics, i.e. a technology integrating precision mechanical engineering, electronic control and software in the design of products and manufacturing processes. One of Ilmar Santos' inventions deals with active lubrication in bearings.

Lubrication is computerized by means of sensors registering the space between the bearing and the shaft. When the shaft is spinning fast it might start to vibrate and rotate within the bearing. Due to Ilmar Santos' invention, this will be registered immediately by sensors feeding a computer with all the necessary information. The computer-controlled valves in the bearing immediately squirt oil under high pressure into the shaft to resist vibrations. The advantages of computer-controlled lubrication are many, e.g. reducing energy loss.

The wind industry as well as the oil and gas industries can benefit from this invention, since they all utilize mechanical constructions in bearings and shafts.

A two-fold honor for Professor Preben Terndrup Pedersen
In March Professor Preben Terndrup Pedersen, DTU Mechanical Engineering, received Den Maritime Pris (the Maritime Prize) for 2010 for his crucial research in ships and offshore constructions. Preben Terndrup Pedersen is only the second prize winner after shipowner Mærsk Mc-Kinney Møller who received the prize in 2007.

Furthermore, Professor Terndrup Pedersen was named honorary doctor at NTNU, Norges Teknisk-Naturvidenskabelige Universitet (Norwegian University of Science and Technology) at Trondheim, in May 2010.

NTNU is a part - like DTU - of the Nordic Five Tech university cooperation. The grounds for his nomination included a special mention of his impressive and extensive high-quality research activities. Also, he was praised as "one of the most recognized and respected researchers in the international ship and sea technology environment."

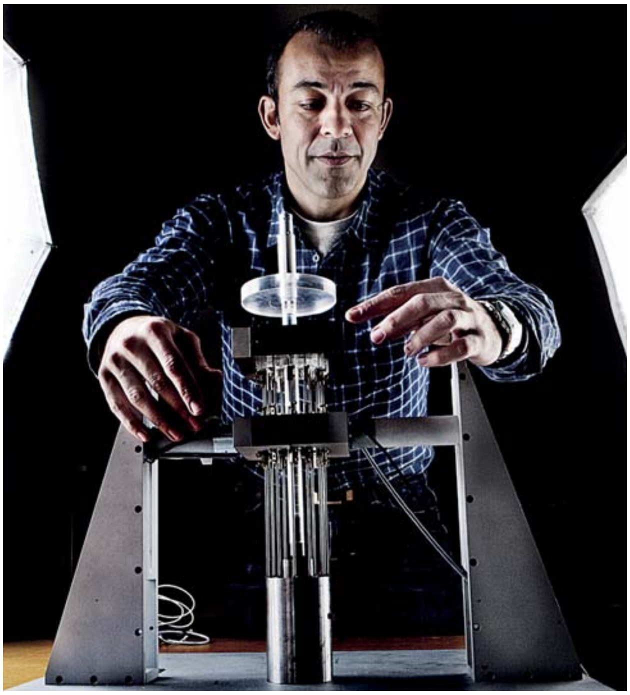
Professor Terndrup Pedersen was also recognized for his close collaboration with the industry. To a great extent his research results have given rise to innovation in the practical ship technology.

Professor Preben Terndrup Pedersen is named honorary doctor at NTNU in Trondheim, Norway.

Highlights 2010

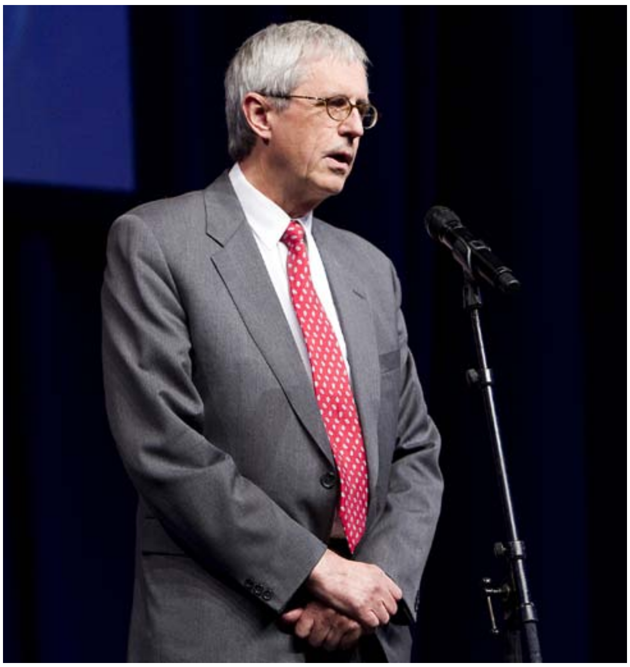
Associate Professor Ilmar Santos defended his doctoral thesis
In April 2010 Ilmar Santos, associate professor at DTU Mechanical Engineering, defended his thesis "Mechatronics applied to machine elements with focus on active control of bearings, shaft and blade dynamics".

One of Ilmar Santos major achievements is the designing of actively-lubricated oil and gas bearings, which can increase damping and enhance rotor dynamics stability.



Associate Professor Ilmar Santos

Professor Viggo Tvergaard



Professor Viggo Tvergaard is awarded the Alexander Foss Gold Medal
In May Professor Viggo Tvergaard, DTU Mechanical Engineering, was awarded the Alexander Foss Gold Medal for his meritable achievements in engineering. His work has centred around structural mechanics, including stability of construction, and he is a pioneer in the field of elasto-plastic stability.

Viggo Tvergaard has done basic research in the modeling of strength properties of materials, and he has set up models for the effects of structural defects in materials.

Viggo Tvergaard is one of the most influential scientists in the modeling of mechanical properties of structural material.

Expertise in lubrication is rewarded with Swedish award
In December Associate Professor Ion Marius Sivebæk, DTU Mechanical Engineering, was awarded SEK 100,000 from the Jacob Wallenberg Foundation for his "research and development in the field of material science."

Dr. Sivebæk's comprehensive studies are based on a combination of theoretical computations and experiments covering lubrication at nano-level.

One of his achievements deals with the diluting of lubrication film and its transition from liquid to solid form. His findings contribute, directly or indirectly, to numerous advances, e.g. to prolong the life of the machine parts.

Kungliga Ingenjörsvetenskapsakademien (The Royal Swedish Academy of Engineering Sciences) is responsible for The Jacob Wallenberg Foundation.

Associate Professor Ion Marius Sivebæk

Professor Jesper Hattel (left) is Teacher of the Year 2010.

Jesper Hattel - Teacher of the Year 2010
"Jesper is an awesome communicator."
"He makes a huge effort when preparing for every lecture."

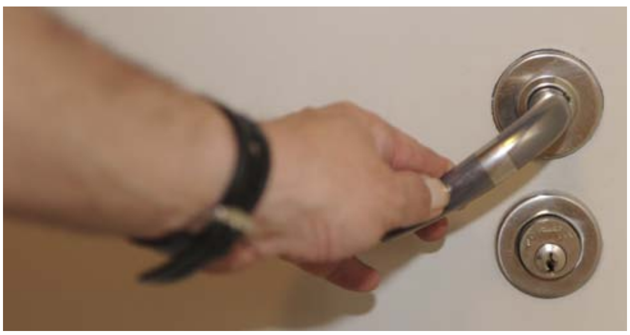
Those were just a few of many words of praise directed at Professor Jesper Henri Hattel, DTU Mechanical Engineering, when he was elected Teacher of the Year 2010 by the Polytechnic Student Association for his teaching in process technology.

To receive the distincton, nominees must have made extraordinary performances to raise the quality of teaching, yet keeping it captivating and relevant for all students at the course, and Professor Hattel fully met all expectations.

The engineering students nominate the candidates, and the Polytechnic Student Association is responsible for the election. Teacher of The Year is the greatest honor in university teaching at DTU, and the award ceremony is a traditional element at the university's annual celebration.

Self-cleaning Surfaces

How many door handles have you touched today - in your home, at the workplace, in a café, or in a public bathroom? How many times have your family or co-workers, other café customers - or whoever you bumped into during the day - opened or closed the same doors? Hands are among the dirtiest parts of the body, and germ-laden door handles can cause infections that easily spread from person to person. Taps, kitchen tables and other surfaces may also transmit viruses triggering colds, flu and even severe staph infections. In hospitals dirty surfaces pose a high risk, especially to the elderly and the many patients with a weak immune system. It takes meticulous and frequent cleaning to radically decrease the risk of spreading numerous infections. Clearly, this is no easy task to implement in a cost-saving environment.

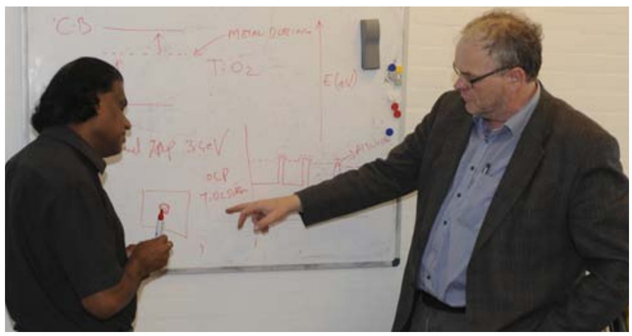


The good news is that two researchers at DTU Mechanical Engineering, Professor Per Møller and Associate Professor Rajan Ambat, are breaking new ground in the field of self-cleaning coating materials.

Active Surface
Associate Professor Ambat is part of a project team that investigates the potential of self-cleaning surfaces on metallic surfaces, for instance door handles and hospital instruments. Associate Professor Ambat says that his project focuses on developing self-cleaning and anti-microbial surfaces on aluminium alloys or steels using photocatalytic titanium dioxide (TiO_2) based coatings together with nanostructuring. This work is just one of many projects involving the Tribology Centre at the Danish Technological Institute. The outcome of their mutual efforts is the development and characterisation of a TiO_2 coating based on state-of-the-art plasma technique for the purpose of creating industrially relevant applications. In general, photocatalytic means that if titanium dioxide is applied as a coating to any surface, the surface becomes active when exposed to ultraviolet (UV) light, and anything that touches the surface will decompose because the energy in UV radiation is converted to chemical energy degrading organic dirt.

This process is the key to innovative coating solutions which will help not only citizens and hospitals but also architectural firms and many industries to attain higher levels of hygiene, ease maintenance and, most likely, reduce expenses.

Essentially, Associate Professor Ambat and Professor Møller work on the same idea, but they develop it in two very different ways. In short, they enable the coating of a



Associate Professor Rajan Ambat (left) and Professor Per Møller.

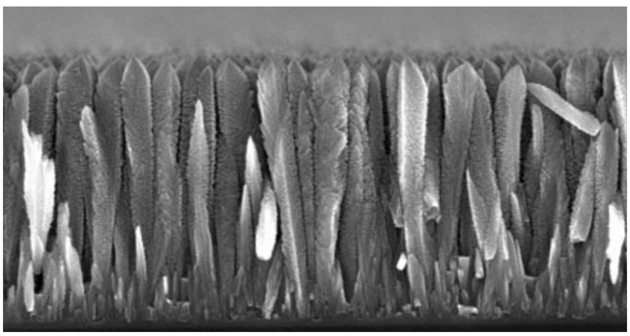
surface to destroy actively bacteria, viruses, harmful gases, air and water pollutants among others. The active coating is applied to the surface. It is still necessary to clean the surfaces, but while a particular surface has to be cleaned maybe two or three times a month – depending on the type of surface – it should only be cleaned once every second month if you set up a self-cleaning surface.

Tiny Little Glass Balls with a Huge Effect
Professor Møller says that his own project is concerned with paint. Cleaning or painting the exterior woodwork of a house about once a year can be a time-consuming drag, but it is often needed to get rid of algae, fungus, moss and other organic sources. Together with Dyrup, the large paint producer, a solution has been found which can postpone the strenuous paint job for several years. By blending microscopic glass balls with a coating of TiO_2 and integrating it into the paint, Dyrup will be able to

…for the Dirty Job and Improved Hygiene

produce self-cleaning paint. This new paint will not only do the dirty job of keeping the woodwork clean for a longer time but also improve the durability.

Several paint producers have tried to blend nanoparticles with TiO_2 in paint before, but experience shows that when this type of paint is exposed to ultraviolet (UV) light it will release short-lived, but rather aggressive free radicals (OH), and as a result not only algae and dirt but also the paint will decompose due to the strong oxidising (OH) radicals. However, replacing the nanoparticles with the microscopic glass balls is the perfect solution. It works well. Moreover, nanoparticles in paint usually constitute a health risk, because the particles can penetrate the skin of humans and animals. As it is crucial to eliminate health



risks associated with integrating nanoparticles in coating, a solution had to be found and the tiny glass balls proved to be the right approach.

Actually, old knowledge is revitalised by putting all the little bits together in new ways. With the new coating several goals are achieved – product life is prolonged, safety increased and compliance with environmental requirements ensured.

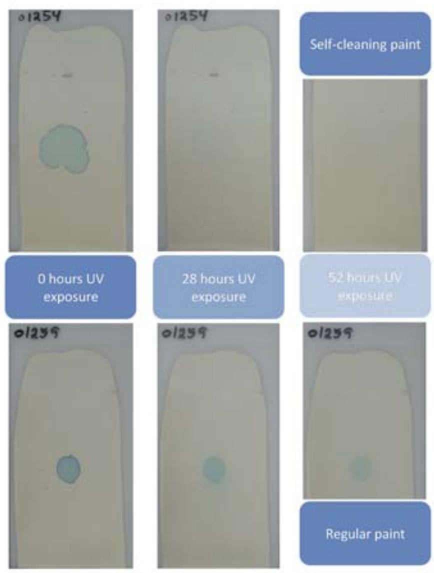
Basic Research Available to the Real World
The two researchers make a point of emphasising that their projects are aimed at the practical world – solving real problems. Professor Møller says that they carry out basic research, but do not consider it as purely academic exercises. The projects should result in materials or products that are useful for the industry and for society in general. Thus, they also communicate closely with their partners all the time. They exchange ideas, test the ideas and make experiments – it is always an iterative process where understanding down to the atomic level is a must. It is very much a give-and-take process.

As one of the latest developments so far, Associate Professor Ambat and Professor Møller together with groups at the Danish Technological Institute attempt to modify the technology by doping the coating with copper, iron and more elements. The idea is to enable the surface to become active when exposed to “normal” light, which means non-UV light. This will be an important step because the need for UV light as sole light source is avoided.

Both researchers work in close collaboration with a number of industrial partners as well as other institutions. Associate Professor Ambat’s partners are the Danish Technological Institute, IPU, DTU-Bio, PAJ System Teknik, and Alucluster. This project was initiated in 2009 and is expected to be completed by 2013. Presently, the team explores the commercial possibilities of the coating in various technological sectors.

The Danish National Advanced Technology Foundation supports the project with a DKK 9.5 million grant. The total budget is DKK 19 million.

Professor Møller cooperates with Dyrup. This project was initiated in 2008 as an industrial PhD project and is supported by Dyrup.



Danish Wind Industry in the Lead with Yaw Drive Unit

How to steer the wind turbine nacelle so that it always holds the correct position towards the wind - yet reacts to its changing directions? The yaw drive system ensures that it happens automatically.

The yaw drive system enables the nacelle to adjust the position towards the wind, to brake, and to remain unmovable when it has reached the right position. The nacelle is yawed and does not move again until the wind changes direction. However, these mechanical systems are about to be upgraded significantly, and new high-end yaw drive units shall consolidate the Danish leading position in the development and production of wind turbines and turbine components. The current low-technology solution with separate units will be replaced by a high-technology solution containing the so far separate components - the brake, the toothed rim and the plain bearing - to constitute a single, advanced unit.

Today's yaw systems are typically adjusted to each specific type of wind turbine, whereas the new mechanism will be segmented and customised to match various types of turbines. The components can be assembled to satisfy needs and expectations, no matter whether it is a 2.5 megawatt, 5 megawatt or almost any other wind turbine. The built-in flexibility has a wide potential.

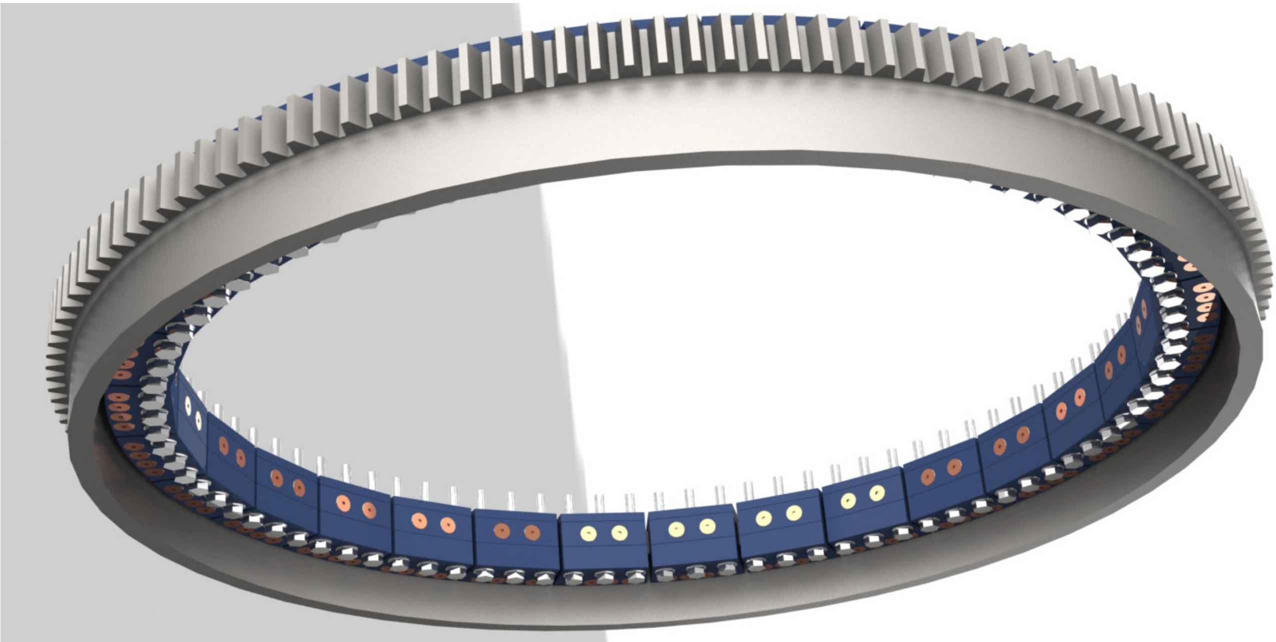
It is no simple task to develop such a sophisticated mechanism and the development team faces big challenges as the work progresses. However, when the project is completed in three years the wind turbine producers can look forward to new solutions with enhanced functionality and less noise emission, as well as they will be more cost-effective than known solutions. A cheaper and far better product will be the result.

The development team is composed of DTU Mechanical Engineering contributing with the theoretical and experimental expertise, Svendborg Brakes A/S and Kirkholm Maskiningeniører A/S, representing the industry, both companies with many years' experience as suppliers of components to the wind turbine industry. The Danish National Advanced Technology Foundation supports the project with a DKK 10 million grant. The total budget is DKK 18 million. The project was initiated in August 2010. Jan Otto Sørensen, Svendborg Brakes A/S, is Executive Project Manager, and Kjeld Bruno Pedersen is Project Manager for Kirkholm Maskiningeniører A/S. Professor Peder Klit is Project Manager for DTU Mechanical Engineering as well as Professor Leonardo de Chiffre is a key participant.

From Plus to Minus Degrees, from Sand to Snow

The project involves a considerable amount of research and testing and high standards as regards data collection and materials must be met before designing the right product. Wind turbines work in different and often extreme weather conditions, in dry, hot deserts with sandstorms and large shifts in temperature from day to night, in cold polar areas with snow and ice or in saline, wet winds in the North Sea - the wind turbines must operate effortlessly in all conditions. Moreover, close to inhabited areas low noise is a requirement of the turbines.

Professor Klit states that the project proceeds well and the three partners cooperate effectively. He and Leonardo de Chiffre find that it is always inspiring to work with the industry. The motivation is also high with his PhD student Konstantinos Poulios, who conducts extensive research and mapping-out work, and de Chiffre's Postdoc student Jochen Hiller, who carries out detailed measurements and model building.



At DTU Mechanical Engineering the main task is to produce the theoretical foundation, which is the prerequisite for the actual construction of the product later to be designed by Kirkholm Maskiningeniører A/S. Professor Klit continues that they deliver generic data, for instance for the braking surface, plain bearing surface and lubrication oil - all major elements in the development of new solutions. The project is still in the experimental phase so there is a lot of activity at DTU. However, all three members of the consortium are actually involved, making calculations and carrying out experiments as well as they share experiences and results regularly.

A Mass of Almost 100 Tons

After finishing the research phase, including the data collection and model making, Svendborg Brakes A/S and Kirkholm Maskiningeniører A/S will start constructing and testing the components. This means working with large and heavy machine components - the toothed rim alone is three metres in diameter. It takes four motors to drive the turbine cap, or nacelle, and the plain bearing must be big enough to carry the load from 100 tons. The machine parts are so large that it will be a huge challenge just to keep normal tolerance standards. Few machines can manufacture components of this size. Regardless of the enormous dimensions, the cap must operate with optimal precision at all times.

The future test phase will cover the chosen solutions and testing must be performed as close to real-life conditions as possible. Since the wind turbine industry, for obvious reasons, is disinclined to provide wind turbines in megawatt size, Svendborg Brakes A/S will design a special test nacelle which is capable of operating under different load capacities, temperatures and wind conditions. The test nacelle will also be exposed to dust, sea salt and other particles.

Professor Klit says that all participants benefit from the growing knowledge level. At DTU Mechanical Engineering we increase our knowledge of materials, friction and lubricants, and our two partners acquire first-hand experience with highly educated theorists, like our PhD students, and what they can offer the practical world.

It is the hope that the buyers of the new yaw drive units will benefit the most. They get more for their money and they get more than a brake, they get a high-technology product that holds the potential to outdistance competitors. Most likely, this project may secure the leading position of the Danish wind turbine industry.

New Nordic Master in Maritime Engineering

DTU Mechanical Engineering is the initiator and coordinator of a new two-year master programme in maritime engineering to be provided by five Nordic technical universities. The first year covers topics of maritime engineering, naval architecture and offshore structures, their design, construction and operation and their interaction with the environment. In the second year students specialise in one of the five key subjects: Ship operations, ocean structures, passenger ships, ship design and small craft.

The students choose one of the universities for the first introductory year and select a line of study in one of the four other universities for their second year of specialisation, so the student will stay in two different Nordic countries before completing the programme.

Associate Professor Poul Andersen.

2010 was a year of defining and structuring of the new master programme. For the five technical universities it was also a fruitful phase of harmonising different educational cultures and building a foundation for mutual and continued inspiration.

The ambitions, however, go beyond the Nordic countries. Thus, the master programme aims at attracting high-level candidates from the entire world and at enhancing the current strong position of the contri-buting universities in the scientific maritime disciplines.

The programme is facilitated by means from the Nordic Council of Ministers and is offered by a consortium of the five Nordic technical universities working together within the framework of the Nordic Five Tech university alliance and is provided by the following departments:

- **Aalto University:** Faculty of Engineering and Architecture, Department of Applied Mechanics, Helsinki, Finland
  Specialisation: Passenger ships

- **Chalmers University of Technology**: Department of Shipping and Marine Technology, Gothenburg, Sweden.
  Specialisation: Ship design

- **Norwegian University of Science and Technology**: Faculty of Engineering Science and Technology, Department of Marine Technology, Trondheim, Norway
  Specialisation: Ocean structures

- **KTH, Royal Institute of Technology**: School of Engineering Sciences, Department of Aeronautical and Vehicle Engineering, Naval Architecture, Stockholm, Sweden
  Specialisation: Small craft

- **DTU, DTU Mechanical Engineering**: Section of Coastal, Maritime and Structural Engineering, Lyngby, Denmark
  Specialisation: Ship operations

Associate Professor Poul Andersen, who is Project Manager at DTU Mechanical Engineering and the initiator of the new master programme, says that it is a response to future challenges in the maritime field.

The demand for highly qualified maritime engineers is increasing in companies, and there is also a general call for safer, more energy efficient and more environmentally friendly ships, ocean structures and operations.

The Nordic countries have long and rich traditions within maritime engineering, and each of the five universities has their own unique expertise. By integrating their top competencies into the new master programme their position in the international educational environment is significantly strengthened. The first students start in September 2011.

Promising Future

Before completing the master programme, the students write a thesis that will be evaluated by two professors, one from each of the two involved universities.

An outside examiner may also contribute. The Nordic Master in Maritime Engineering is a double degree programme and the new candidates will be presented with two MSc diplomas – one from each of the two universities.

The new master candidates will be attractive to a number of industries, for instance shipping companies, and many candidates are expected to be in high demand as consultants within their line of specialisation.

From DUT to DTU

Chinese Cindy Li, 29, is one of the students who has responded to the new programme. Cindy holds a bachelor's degree in naval architecture and marine engineering from DUT, Dalian University of Technology. She has worked in Shanghai since 2004 and through two Danish colleagues she is familiar with DTU and impressed by the excellent students graduating from this University. She noticed the Nordic Master in Maritime Engineering when browsing on dtu.dk at the end of 2010 and it attracted her immediately.

Cindy Li chose DTU in order to further her career development in maritime engineering and to enrich her life. She looks forward to acquiring first-hand experience and knowledge of advanced maritime engineering from the professors there. Besides, it is a good chance to join a culturally diverse environment with students from many countries. After graduation she plans to take part in the fast growth of Chinese shipbuilding. Danish shipowners and companies increasingly do business with Chinese shipyards and based on the knowledge she acquires in Scandinavia she can be a mediator between Chinese shipyards and Danish maritime companies.

RADIADE Brings Models Closer to Reality

Heightened environmental requirements have a huge impact on the entire marine sector and certainly affect the area of emission in marine propulsion. To a great extent the RADIADE project is necessitated by stricter emission regulations for marine diesel engines.

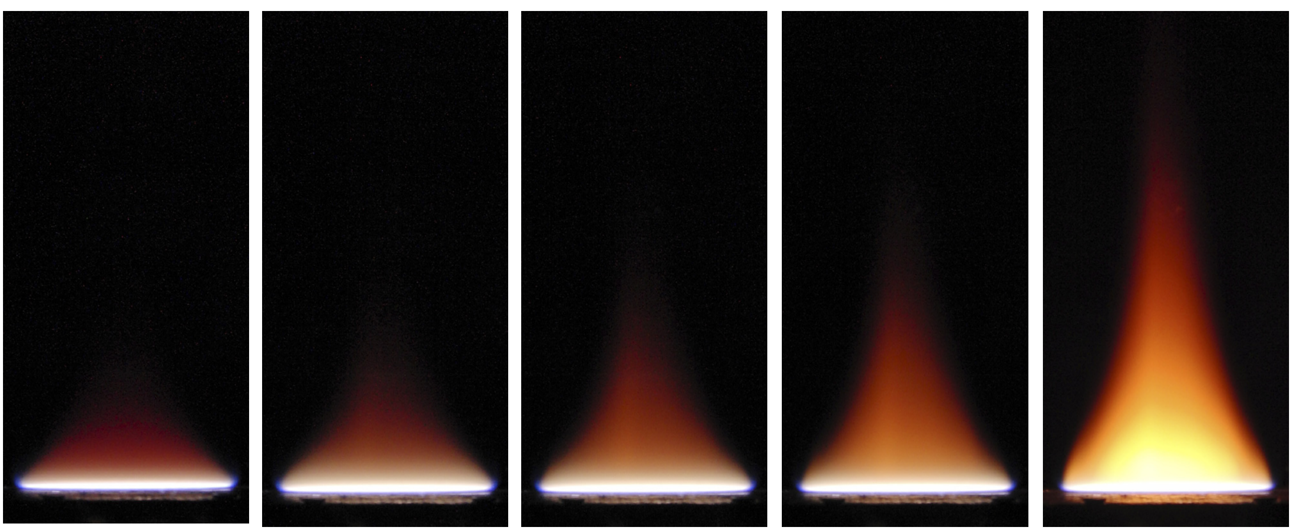
Background

About 8% of the energy used for all transportation in the world is spent on marine propulsion. In general, it is well spent due to the high efficiency of transporting large mass units on ships with highly efficient, large diesel engines. Thus, in terms of CO_2 emission and energy consumption this means of transportation is very efficient. There is a disadvantage though – large amounts of emitted pollutants, especially nitric oxides (NOx), sulphur oxides (SOx), unburned hydrocarbons (HC) and soot. These pollutants all have a direct detrimental effect on human health. Many also lead to the formation of secondary pollutants in the atmosphere. Soot is also a growing threat to the global climate, since soot deposits on the Arctic ice reduce the reflection of sunlight, leading to increase in global warming.

The International Maritime Organization, IMO, has responded to the challenge by tightening the current regulation on NOx emission with 25% from 2011 and with 80% within specific emission control areas from 2016. It is a demanding task to redesign diesel engines for such low-emission limits without significantly lowering the fuel efficiency and thus increasing CO_2 emissions. Computational Fluid Dynamic (CFD) models describe fluid flows and will become a key design tool in marine engine development as they usually reduce time consumption and costly experiments, while providing more detailed and precise information than measurements usually can.

Associate Professor Jesper Schramm, DTU Mechanical Engineering, is Project Manager of the RADIADE project. He explains that in order to reduce NOx emissions it is necessary to know how they are formed – and the formation is closely related to temperature conditions in the engine. The RADIADE project focuses on the ability to predict the temperature distribution in the combustion chamber, as NOx is formed under high temperatures. The team start out by working with CFD models and submodels and subsequently they try out the results in real-world experiments. The core idea is to enhance state-of-the-art CFD models resulting in improved predictions, so that the results of the whole project may lead to sharper design tools. This will facilitate the development of marine

Photos of radiation from a laboratory flame at DTU-MEK. The first flame from the left has strong radiation from hot gas and no radiation from soot. Toward right the radiation from soot is being increased by changing the flame conditions until it finally becomes dominant. These investigations are important in order to validate radiation as well as soot formation models.



diesel engines which are in compliance with future emission regulations.

Details

Detailed computational modelling processes inside combustion engines involve modelling of combustion, fluid flow and heat transfer phenomena and their mutual interactions. Currently, radiant heat transfer modelling is the weaker link in this sequence, so the RADIADE project team will work on improvement in this field.

The approach will be to adopt large, detailed and computationally demanding modelling of radiation phenomena developed by physicists for engineering purposes. But since computational resources are limited, a compromise must be found between fidelity of the employed model and computational times that are acceptable for the use within an engineering framework. This will be done by systematic sensitivity analysis of model simplifications and thorough validation against experimental results. These studies are necessary to determine the most efficient use of the computational power and reveal the deficiencies of the modelling approach. Different laboratory flames with increasing complexity levels will be used for validation purposes.

Assistant Professor Anders Ivarsson, who will be in charge of the experimental team at DTU Mechanical Engineering, says that this incremental approach serves to identify deficiencies in the radiation model and that the most complex laboratory flame should comprise the features of a true diesel engine flame as much as possible. Finally, the model will be validated against measurements performed in the MAN Diesel & Turbo test engine.

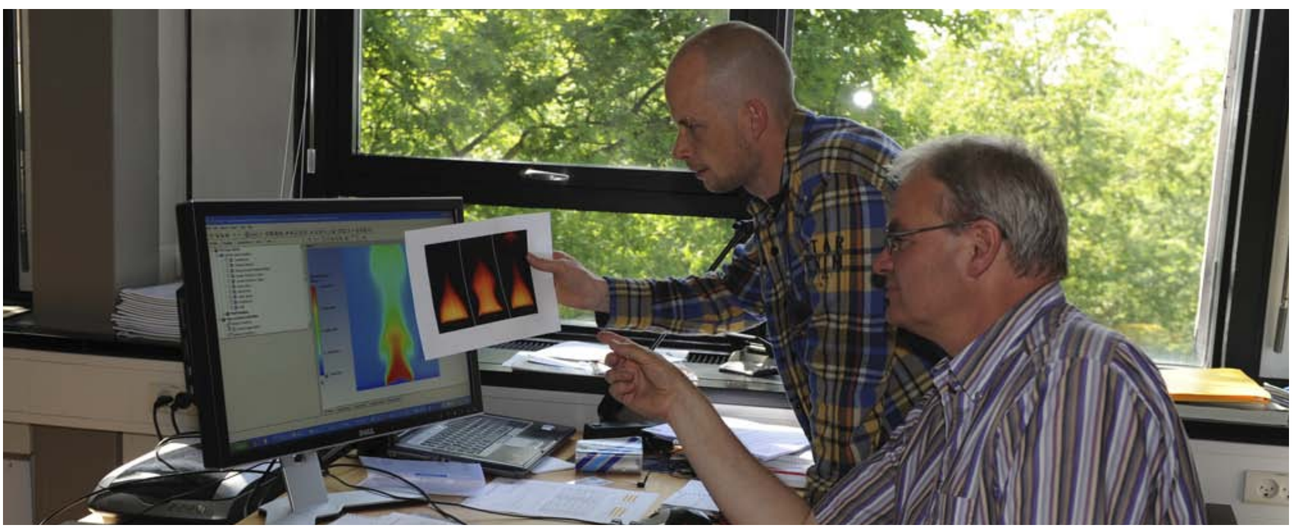
Collaborators

The RADIADE project is complex and involves several international collaborators representing the most competent research environments and the world's largest producer of large marine engines: DTU Mechanical Engineering, Norwegian University of Science and Technology (NTNU), Sandia National Laboratories in California (SANDIA), RISØ DTU, Politecnico di Milano (POLIMI) and MAN Diesel & Turbo.

Numerous PhD students and postdocs from the participating universities will contribute to the five-year project. The project is organised in six tasks, and the plan is to send PhD students and Postdocs from DTU Mechanical Engineering and RISØ DTU to Sandia, POLIMI and NTNU. Similarly, researchers from POLIMI and PhD students from NTNU will spend time at DTU.

The RADIADE project has a total budget of DKK 22.1 million. The Danish Council for Strategic Research, a part of the Danish Agency for Science, Technology and Innovation, has granted DKK 12.3 million.

Assistant Professor Anders Ivarsson (left) and Associate Professor Jesper Schramm.



Improving the Reliability of Drivetrain Components

For the next six years the REWIND Centre will be the breeding ground for major research activities aimed at improving the manufacturing processes of drivetrain components in wind turbines, and the results of the Centre's efforts may very well impact the entire wind industry.

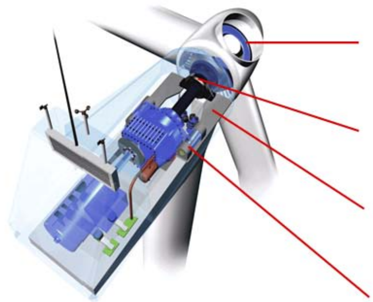
The REWIND Centre involves no less than twelve university and industry partners and an extensive list of researchers, including eleven PhD students, of whom three are industrial PhD students employed at VESTAS as well as five Postdocs.

Professor Jesper Henri Hattel, DTU Mechanical Engineering, is the initiator and head of the Centre. He spent most of 2010 building up the organisation and applying for research funds.

Professor Hattel explains that the main purpose of the REWIND Centre is to perform strategic research in the field of materials-manufacturing-properties-performance of metallic components in the rotor and drivetrain in large wind turbines, with the ultimate aim of enhancing the reliability, extending the lifetime and arriving at an improved life expectancy prediction of the components.

Moreover, it is also a specific purpose of the Centre to provide the scientific foundation for the Danish strategic effort to build drivetrain facilities at Risø DTU and LORC.

Professor Jesper Hattel.



Outline of the Background

Wind turbines are huge structures subjected to highly dynamic loads arising from the complex interaction between the varying wind field and wake from other turbines, the rotation of the rotor as well as the transmission and the electric generator in the drivetrain inside the nacelle. Consequently, most components in a wind turbine are exposed to highly dynamic loads resulting in wear and fatigue of the components. This may lead to premature failure of single components or even more severe breakdowns of larger parts of the wind turbine.

Typically, offshore wind turbines are more liable to failure, which is particularly unfortunate, since replacing components offshore is a costly affair. The transport and re-erection of new components alone cost a neat sum. Especially, the transmission is a sore point and often fails offshore, which results in a shorter life for the wind turbine.

Thus, wear and fatigue can result in considerable economic costs. Many of the reasons for these problems originate from how the components were manufactured in the first place. Typical manufacturing processes include casting of the rotor hub, housings and frames and possibly also the main shaft as well as forging of main bearings and gear parts. These processes inherently give rise to a non-uniform internal structure and associated properties, including residual stress distributions, and consequently affect the performance of the components during use. For heavily loaded parts such as gear wheels it might be necessary to apply further processing such as heat treatment in order to obtain a wear resistant surface.

in Wind Turbines

The Entire Chain
The research centre addresses the entire chain of materials-processes-components-loading performance in a systematic way with emphasis on heavily loaded wind turbine components, in order to be able to understand, describe and predict the performance of the components during service better than today, thus paving the way for increased reliability and durability of the entire wind turbine.

Professor Hattel states that this is actually a research project of great complexity, but it is necessary to be better at predicting the properties of the components, and it is also necessary to disclose how the different components in the drivetrain interact with the dynamic loads. The demand for sustainable power supply and widespread environmental requirements set the tone for the project. As a starting point, he is certain that in six years improved models for manufacturing metallic wind turbine components in the drivetrain can be offered to the industry. This will be the take-off for achieving the ultimate goal of building wind turbines with a prolonged life expectancy.

The Danish Council for Strategic Research, a part of the Danish Agency for Science, Technology and Innovation, has granted DKK 30.1 million of the total DKK 45.6 million budget. Moreover, the three industrial PhD researchers funded by VESTAS will correspond to an additional DKK 5 million.

The collaborators in the REWIND Centre include DTU Mechanical Engineering, Risø-DTU, AAU-BYG, Vestas A/S, DONG Energy A/S, HelmHoltz-Zentrum für Materialen, Indian Institute of Technology, Vattenfall A/S R&D and MAGMA GmbH.

Coastal, Maritime and Structural Engineering

Research activities

Hydroelasticity of ships
A fully nonlinear calculation using a finite volume formulation with the free-surface captured by a volume of fluid (VOF) technique in a realistic wave environment is developed based on a three dimensional case study of a fine form container ship sailing head sea in a critical wave episode defined conditional on a given response level of the hull girder.

Extreme Value Predictions of Wave- and Wind-induced Responses for Floating Offshore Wind Turbines using FORM and Monte Carlo Simulations
The aim is to advocate for some very effective stochastic procedures, based on the First Order Reliability method (FORM) and Monte Carlo simulations (MCS), for extreme value predictions related to wave and wind induced loads on marine structures. A scaling property inherent in the FORM procedure is investigated for use in MCS in order to reduce the necessary simulation time.

Operator Guidance for Ships Based on Combined Use of Sea State Estimation and Response Measurements
A procedure has been established for the calculation of wave-induced accelerations, hull girder bending moments, or other critical response values to be expected in the event that a ship undergoes course and/or speed changes. The central point is that the response predictions do not rely solely on a mathematical model and the estimated sea state. Thus, past response measurements are also taken into account.

Model for Environmental Assessment of Container Ship Transport
As a consequence of the increased focus on the environmental impact from shipping - especially from exhaust gas emissions - a generic computer model for container ships has been developed. On the basis of the capacity demand, the new DTU model calculates the principal ship particulars for a typical container ship with the desired capacity.

Enhanced Damage Tolerance and Blast Impact Resistance of Composite Lightweight Structures
Two new large research projects with industrial cooperation are aimed at enhancement of damage tolerance of

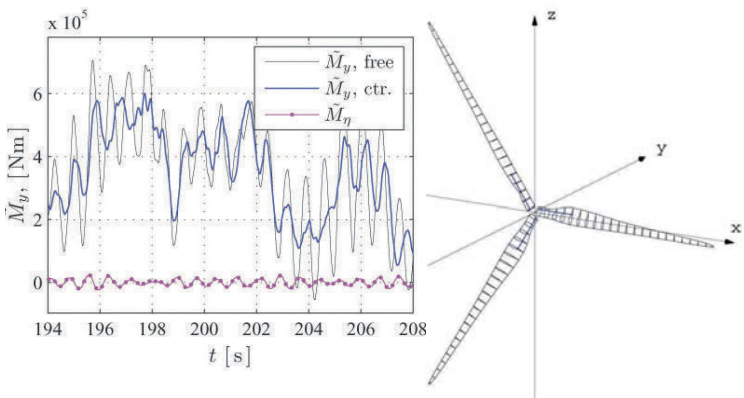
composite sandwich structures in e.g. wind turbine blades and ships and at blast impact resistance of composite military vehicles. Both projects aim at enhancing the structural performance by intelligent composite material architecture resulting in either considerable damage tolerance improvements or enhanced blast impact resistance against especially improvised explosive devices encountered by military vehicles.

Resonant vibration control of wind turbine rotors
A theory has been developed for active control of a combined set of vibration modes in three-bladed rotors. The control system consists of identical collocated actuator-sensor pairs in the form of an active strut near the root of each blade, illustrated in the rotor figure. The three active struts permit addressing a group of vibration modes by suitable combination and calibration of the sensor/actuator signals. Two resonant filters are used to impose resonant damping on the collective and the whirling modes, respectively. The graph shows a simulated record of the moment at the root of a blade for typical turbulent wind load with and without control. It is clearly seen that the resonant control provides a substantial reduction of the vibration level and thereby prolongs blade fatigue life. The dotted line at the bottom of the figure shows the much smaller magnitude of the control moment imposed via the strut.

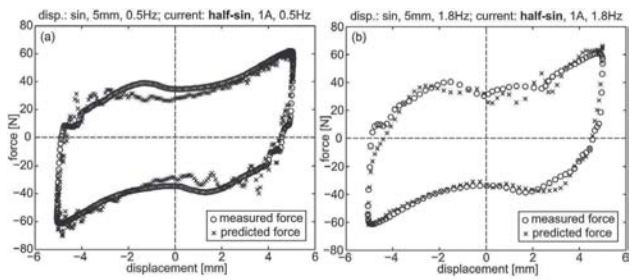
The research topics at the Section for Coastal, Maritime and Structural Engineering deal with coastal engineering, maritime engineering, naval architecture, structural engineering including lightweight composite structures, risk and reliability assessment and environmental issues like reduced energy consumption and emission from ships.

Theoretical, numerical and experimental investigations are carried out using state-of-the-art tools for the design, analysis and operation of large maritime, coastal and land-based structures under environmental loads, such as waves and wind.

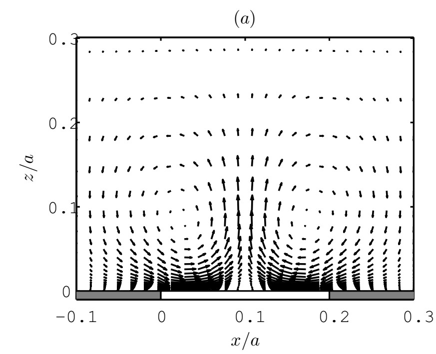
Neural network modeling and control of semi-active MR dampers
The present project concerns the modelling and control of the Magneto-Rheological (MR) damper, which is a semi-active damper that combines large damper forces, fast response time and low power requirements. The characteristics of this type of damper are inherently non-linear, which means that accurate modelling and effective control often requires extensive mathematical models with many system parameters. Thus, the present project con-siders the application of neural network techniques, and as the experimental results in the figure show this approach is quite successful in capturing the behaviour of a rotary type MR damper. The research is conducted in collaboration with the Swiss Federal Laboratories for Materials Science and Technology (EMPA).



Roughness-induced streaming in turbulent wave boundary layers
Numerical simulations involving turbulent oscillatory wave boundary layers over spatially varying bottom roughness have been performed, based on an OpenFOAM model solving Reynolds-averaged Navier-Stokes equations, coupled with k-ω turbulence closure, modified in a simple way to account for anisotropic normal stresses. This is a problem of both engineering and geophysical interest, having relevance e.g. to coastal flows around stone protection layers commonly used at the base of coastal structures.



Transient waves generated by a moving bottom obstacle
A fundamental theoretical and numerical study of the evolution of transient water waves generated by a wide bottom obstacle moving over a horizontal bottom have been conducted. This phenomenon can be considered as one of the elementary mechanisms in tsunami generation e.g. from landslides or subsea earthquakes, but it is also relevant to flow over submerged fixed obstacles. The research has included a variety of flow conditions such as sub-critical, trans-critical and super-critical conditions. One important objective has been to evaluate classical semi-analytical methods obtained from e.g. the forced KdV equation, the non-linear shallow water equations (NSW), and the forced linear shallow water equations (FLSW).



Computed (period-averaged) secondary transverse circulation cells, resulting from a wave boundary layer simulation where the primary flow is directed into and out of the page. The grey (white) bottom regions depict rough (smooth) patches

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Thermal Energy Systems

Research activities

- Thermal energy systems modeling, simulation and design. We actively develop advanced tools for analysis and optimization with emphasis on process optimiza tion, energy efficiency, exergy methods, and automatic control.

- Power production processes: Steam turbines, gas turbines and fuel cell systems. Research activities include energy optimization of propulsion systems for large ships, analysis of fuel cell systems, and compressed air electricity storage.

- Refrigeration, heat pump technology and industrial energy savings. Refrigeration activities centre on new refrigerants and process integration in refrigeration systems.

- Biomass for power and fuel production. The work is focused on processes for integration of production of power, heat and biofuels.

Examples of research projects:

Propulsion systems for large ships
Until recently very few environmental regulations existed for the shipping industry; however, currently drastic legislative actions are taken on global and national levels. In a Danish context, the merchant navy is responsible for CO_2 emissions of similar magnitudes as those of the rest of the society.

The research at the department is aimed at designing prime mover concepts for ships that reduce the environmental and human health impacts compared with than today's engines, including economical, legislative and practical considerations. Concepts considered include slow-speed, two-stroke diesel engines with waste heat recovery systems as well as gas and steam turbine combined cycles. As for the waste heat recovery systems, both conventional steam cycles and cycles based on alternative working media are considered.

The basis for the research is advanced thermodynamic simulation models, which are used to design and optimize novel prime mover systems. In addition, they are used to develop more simple tools that can be used by the shipping industry to improve the performance of existing machinery.

Fuel cells
Solid oxide fuel cells (SOFC) work at high temperature levels (700-800°C) and they are interesting for CHP applications (up to 1 MW) as standalone plants. Different plant concepts with different reforming processes as well as different fuels are under investigation. Due to their operation temperature SOFCs are also interesting in combination with other traditional technologies such as gas turbines, steam turbines and Stirling engines for CHP applications. Different power classes from a few kW and up to large MW classes are possible to design with high electrical efficiencies (50-70%). We are studying the possibilities of combining biomass gasification with an SOFC plant.

PEM fuel cells work at low temperatures of about 70-100°C which are suitable for a variety of applications such as transportation, forklifts, mobile phones, etc.

In a project financed by Danish National Advanced Technology Foundation we are investigating a PEM fuel cell based plant for transport applications. Different aspects are studied, such as efficient cooling loops and efficient possible fuel recycling methods.

Modelling and optimization of evaporators
In both refrigeration systems and power plants the evaporator is a central unit. Its design influences operation and efficiency significantly. We study details of refrigeration evaporators for both conventional refrigerant s and modern natural refrigerant, e.g. CO_2. In power plants the evaporator is a central part of the boiler, new evaporator layouts improve design and performance of the boiler, but also require new control system design.

Biomass utilization for combined heat, power and fuel production
Biomass is an important renewable energy resource.
We work on system optimization for production of heat,

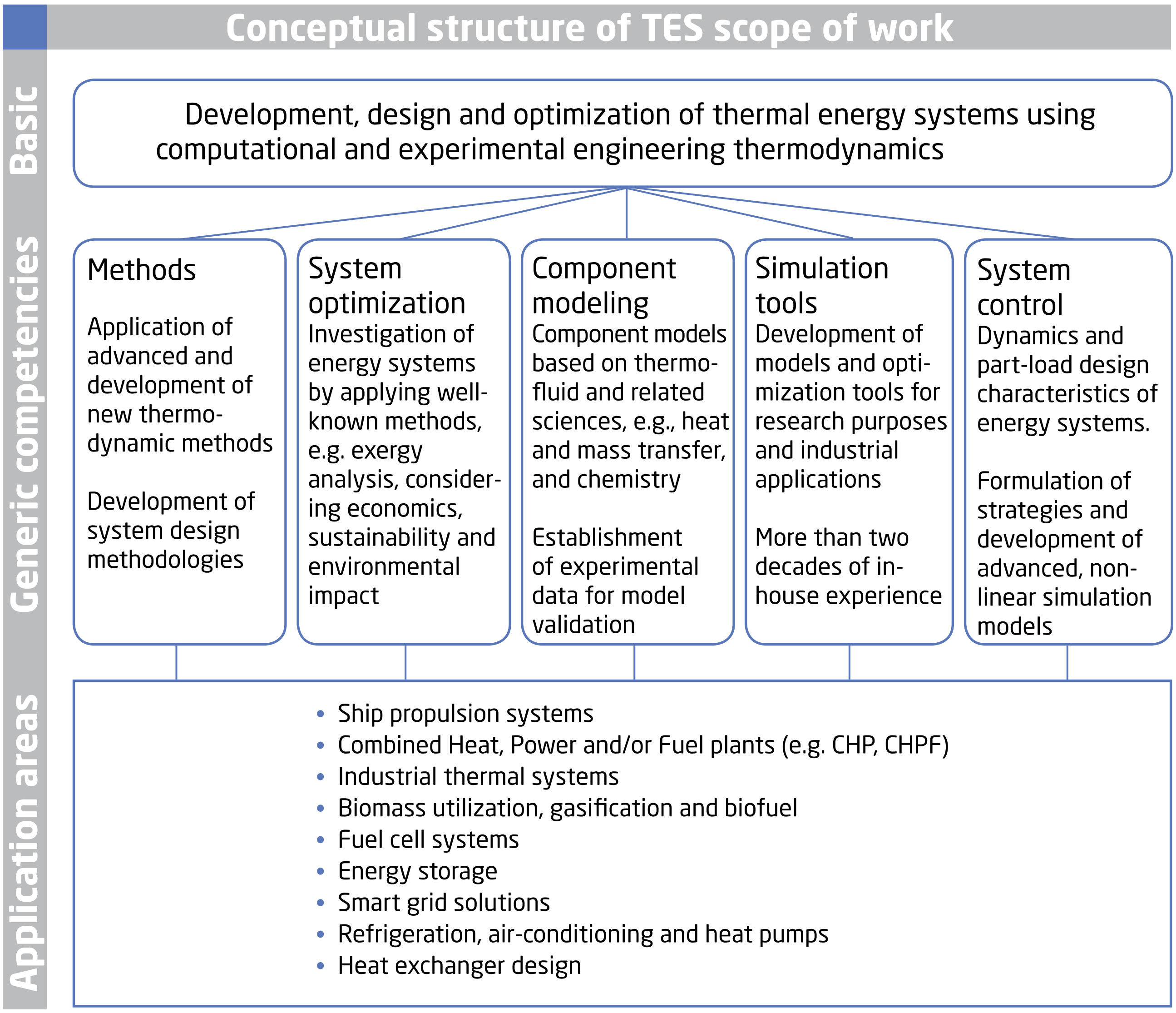
The research in thermal energy engineering is focused on the development and application of advanced thermodynamic methods for optimization of thermal systems as power production, refrigeration systems, heat pumps and biomass utilization.

The group has expertise in numerical modeling of systems and components and the development of simulation tools for these as well as the use of modern methods as pinch analysis, exergy and thermoeconomics.

The group is active in the education of students in the MSc programs Sustainable Energy and Engineering Design and Applied Mechanics.

power and biofuel. System optimization is based on advanced thermodynamic methods such as exergy and thermoeconomics. We work in close cooperation with other groups who develop biomass gasifiers and fuel cells.

Advanced thermodynamic methods for process diagnosis
Thermoeconomics is the integration of economics and thermodynamics based on an exergy analysis. Exergy quantifies primary fuel utilization through and may thus in combination be used for optimization of a thermal system. We focus on different applications of thermoeconomics, e.g., the use of the theory for process supervision and fault diagnostics. The case under study is supermarket refrigeration.



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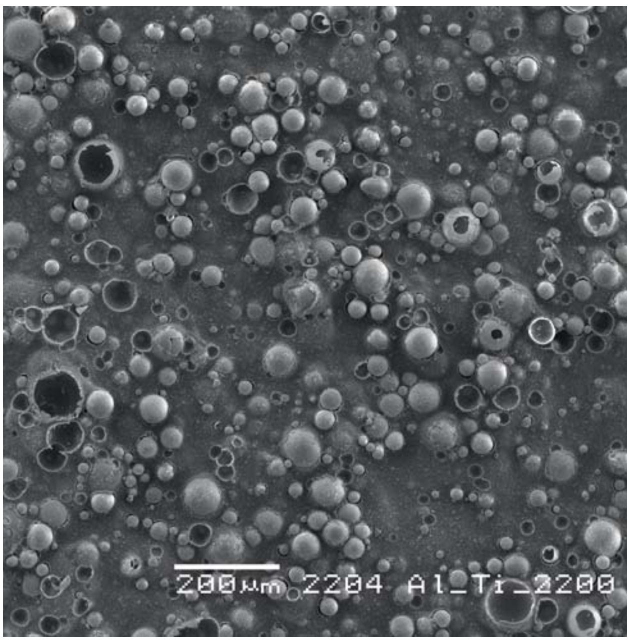
Section

Materials and Surface Engineering

Research activities

Surface engineering and materials design
Surface engineering is the major materials synthesis activity in the section and for this purpose electro-chemical, thermochemical and PVD techniques are applied and further developed.

The research activities in surface engineering cover the entire chain from basic research of generic importance to applied research, engineering and innovation.

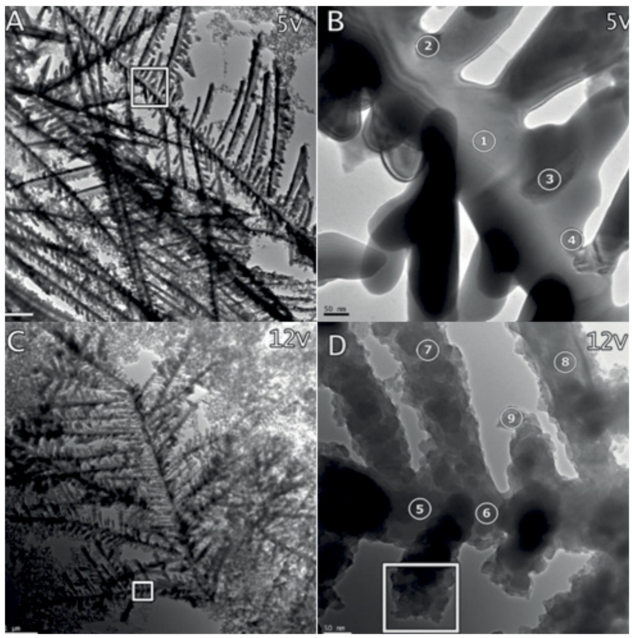


Innovative solutions for self-cleaning surfaces, including self-cleaning paint, were realised in 2010. Thermo-chemical treatment of stainless alloys, which originally started as basic research 10 years ago, was commercialized through the establishment of a spin-off company.

Fundamental research in this topic has continued. Innovative electrochemical surface engineering lies at the origin of materials solutions in SOFCs and highly effective cathode material for hydrogen generation through electrolysis.

Microstructure stability and phase transformations
Materials microstructure evolution during processing as well as during application lies at the very essence of understanding the relations between process parameters, properties and performance.

Understanding the occurring phase transformations in materials form the basis for materials modelling activities.



Among the generic research activities are the development and further refinement of analysis techniques for micro-structure investigation with microscopical, diffraction and spectroscopical techniques.

Among the 2010 activities are focusing on soft materials in collaboration with DTU Cen and detailed EBSD in-vestigations of materials applications as diverse as friction stir spot welded TRIP steel and Ni-electrodeposits.

In 2010 the section Materials and Surface Engineering focused on acquiring financing for research activities related to materials in energy applications through collaboration with industry as well as with other research groups.

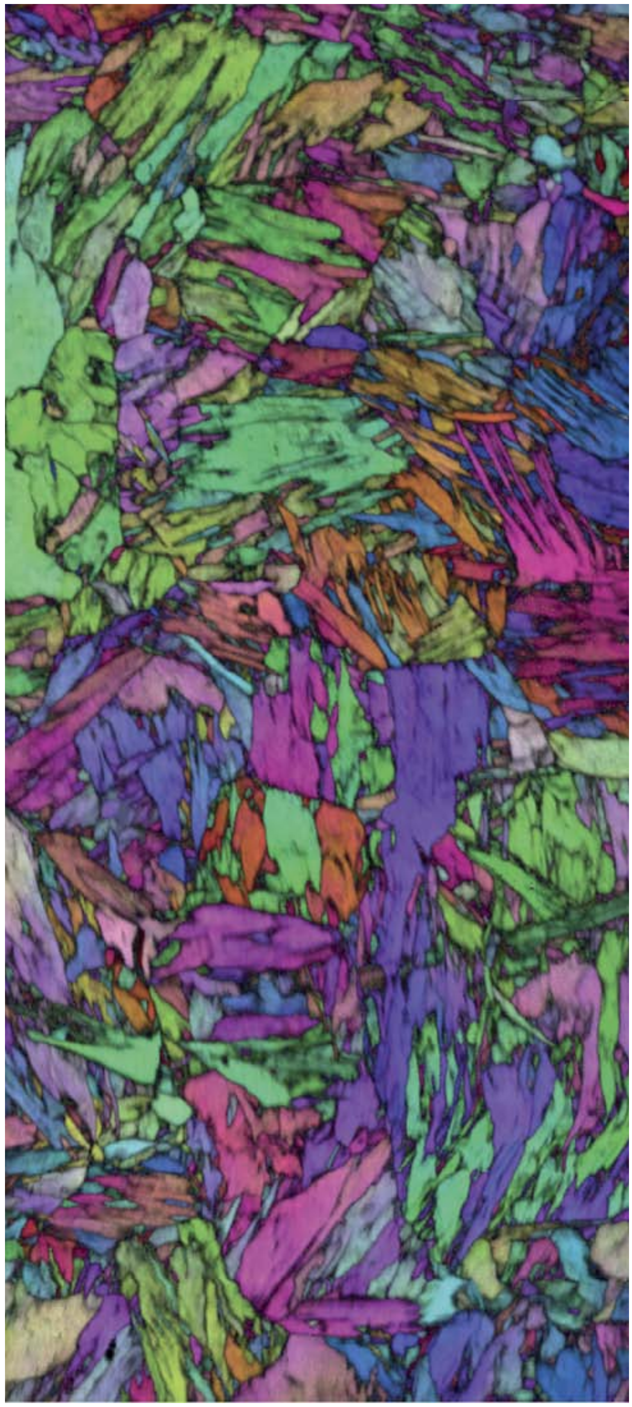
The initiated activities range from materials in solid-oxide fuel cells (SOFCs), wind turbines, bio-mass fired power plants and low overpotential cathode-materials for hydrogen production. Moreover, significant financing was acquired for the initiation of research activities in nano- and biotribology.

Materials performance and degradation
Research in materials performance and materials degradation is concentrated on corrosion, tribology and high temperature performance (creep and corrosion), i.e. the chemical, biological, mechanical and thermal interaction (or combinations thereof) of materials with the environment.

The strategy is to investigate, identify and understand the degradation mechanisms that affect the performance of materials and to use this understanding to predict the life expectancy and design of improved materials solutions.

Research on the development of microscale and high resolution characterization techniques of the electrochemical properties have continued focus in the Centre of Corrosion in Electronics (Cellcor).

High temperature corrosion, particularly hot corrosion, has received particular interest in relation to the design of alloys for application as valves in huge diesel engines as well as coal- and biomass-fired power plants.



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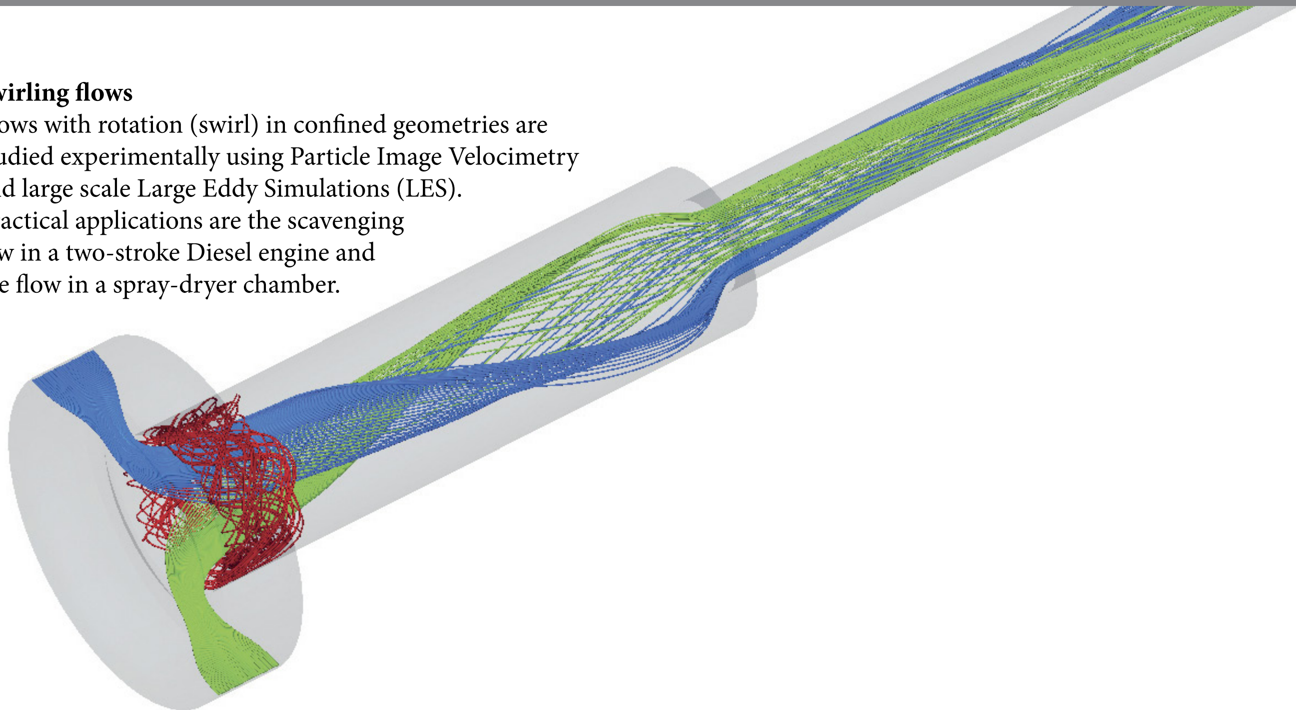
Fluid Mechanics

Research activities

Swirling flows
Flows with rotation (swirl) in confined geometries are studied experimentally using Particle Image Velocimetry and large scale Large Eddy Simulations (LES). Practical applications are the scavenging low in a two-stroke Diesel engine and the flow in a spray-dryer chamber.



Large Eddy Simulations (LES) of the swirling flow in an experimental model of a large two-stroke diesel engine.

The vortical flow structures are described and compared to mathematical models. The measurements also support the very challenging task of finding turbulence models that give reliable predictions in numerical simulations of these flows.

Optimizations of Wind Turbine Blades
New design tools for optimizing wind turbine blades and airfoil sections are being developed. The design tools are based on a newly developed viscous-inviscid interactive aerodynamic code. The code is being combined with an aero-elastic model in order to include the structural dynamics of the blades.

Wind power in Cold Climate
A new PhD project has been initiated together with ARTEC at DTU BYG to investigate icing of wind turbine blades and the problems of operating wind turbines in cold climate. Another ongoing PhD project concerns the possible use of wind power in connection with an existing hydro power station in southern Greenland.

Enhancement of Rotor Performance using Vortex Generators
An investigation on the effect of vortex generators continues through a EUDP funded research project with LM Wind Power and DTU Risø. The project, which contains both an experimental, a numerical and an analytical part, aims at optimizing the use of VGs on wind turbine blades.

Center for Computational Aerodynamics and Atmospheric Turbulence
The research of the center is focused on developing computational methodologies and physical models within wind turbine aerodynamics and atmospheric turbulence. This project is funded by Danish Council of Strategic Research (DSF). More information can be found on www.comwind.mek.dtu.dk

After-treatment of Engine Exhaust
Different diesel particulate filter solutions are investigated experimentally and theoretically. The parameters investi-

The research topics of the Fluid Mechanics Section focus on basic fluid mechanics with main applications directed towards aerodynamics of wind turbines, combustion engines and flow-related industrial process equipment. Fundamental research in fluid mechanics includes laminar-turbulent transition, aero-acoustics, rotating flows, mixing of fuels, room convection, nano- and mesoscale fluid dynamics, and biological flows.

The research is carried out using Computational Fluid Dynamics (CFD), employing in-house developed and commercial computing codes and experimental fluid mechanics (EFD), employing mostly optical methods, such as Laser Doppler Anemometry (LDA), Particle Image Velocimetry (PIV) and related techniques.

gated are, among others, filter temperature, fuel sulphur tolerance, needed fuel additive and allowed filter pressure drop. In a separate project the possibilities of electro-chemical exhaust after-treatment are investigated in collaboration with Risø DTU.

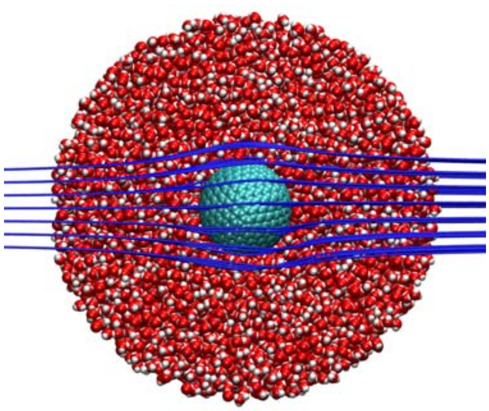
Alternative Fuels for Internal Combustion Engines
The purpose of the project is to evaluate the future of ethanol as a fuel for IC Engines in connection with road transportation. The general idea of the project is to evaluate advantages and disadvantages of biofuels (DME and BTL) for the latest versions of diesel engines for passenger cars.

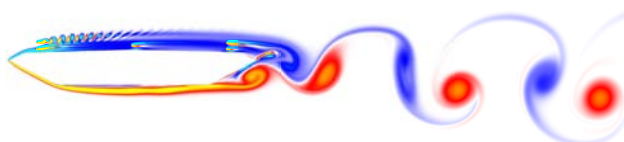
Radiation in Marine Diesel Engines
As the dimension of combustion engines increase, the temperature distribution is becoming more dependent on heat transfer due to radiation. The project is focused on modeling and verification of radiation for understanding emissions formation in large two-stroke diesel engines. The work is financed by Danish Council of Strategic Research (DSF) and involves many international collaboration partners.

Simulation of Wakes and Wind Farms
The mutual influence of wakes of turbines grouped in wind farms are studied using Large Eddy Simulations. The simulations are utilized to derive expressions for mean deficits and turbulence inside wind farms.

Floating Offshore Wind Turbines
The project addresses the calculation of extreme sway, heave and pitch motions as well as moorings, tower and blade loads for floating offshore wind turbines. The basis for the analysis is a wave load procedure taking into account the inertia and drag forces from the waves acting on the floater and the mooring system, combined with an aerodynamic code for the wind-generated loads on the tower and blades.

Multiscale and Multiresolution Methods in Fluid Mechanics
We are developing Lagrangian methods for the simulation of flow at all length scales. The applications range from flow problems at the nanoscale (nanofluidics) to the modeling of large scale turbulence in bluff body aero-dynamics. Our focus in nanofludics is to devise multiscale methods to enable coupling of atomistic simulations with continuum models and to use these techniques to study dynamics of liquids under confinement. This work is performed in collaboration with ETH Zurich. Our work in bluff body aerodynamics involve the development of adaptive, three-dimensional particle vortex methods with applications to bridge aerodynamics.





Multiscale and multiresolution Lagrangian methods are used to study nanofluidic systems – here the flow past a buckyball (left) - and turbulent bluff body flows as it occurs around suspension bridges (right).

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Section

Manufacturing Engineering

Research activities

All research activities of the section are characterized by a combined modeling and experimental approach, where manufacturing metrology plays a major role.

The research is based on the following methods: Process analysis (including analytical and experimental process descriptions and investigations), process modeling (including integrated and multiphysics modeling as well as optimization methods), testing and modeling of materials properties and tribology as well as metrology (including dimensional and geometrical metrology and process metrology).

Material testing is an integrated part of the process chain development providing characterization data for structural design and process simulation.

The technologies covered by the section include metal forming, polymer processing, casting and welding.

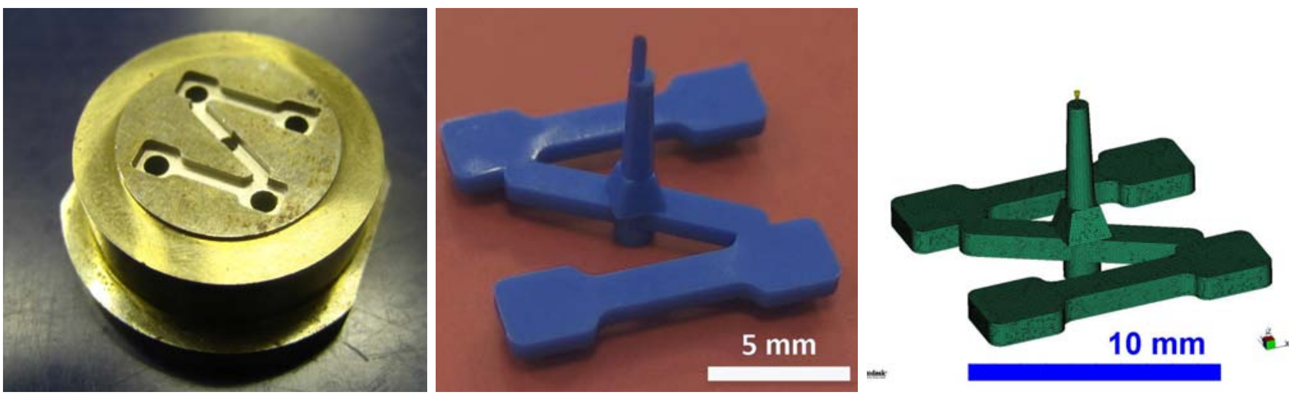
Furthermore micro manufacturing is considered a special technology area due to its special characteristics (covering the above mentioned process technologies as well as mechanical and thermal material removal processes).

Micro manufacturing
The research activities are focused on concurrent development of materials, process technologies and production systems to support industrial production of micro mechanical systems. This includes the development of complex process chains to realize multi-material micro products based on replication processes (e.g. injection moulding and metal forming) and the corresponding tooling technologies. Research involves process characterization and simulation, process chain integration including assembly and quality control of micro mechanical systems as well as product development methods for micro scale.

Process modeling
Although being applied as a valuable tool at user level by almost all researchers at the section, process modeling as a research area in itself is a separate theme. The basic philosophy of the research follows two pathways:

- A more basic science oriented pathway with the aim of describing and modeling the basic physics of the considered processes at a sufficient level for understanding their nature and being able to predict their influence on the final manufactured products.

- A more application oriented pathway, which based on the models as described above, aims at being able to improve and optimize the manufacturing processes with numerical simulation tools, thereby achieving enhanced products regarding choice of process, materials, geometry, etc.



Micro injection moulding: two-cavity micro tool (left), micro dog bone part (center) and meshed model (right). Polymer product: polyoxymethylene BASF Ultraform H2320 004, part volume = 75 mm^3, mass = 91.3±0.3 mg. Modelled part: 1000000 3D elements, 100 μm mesh size.

The research of the section covers manufacturing engineering in a broad sense. The research involves theoretical, numerical and experimental approaches. The main activity areas cover a wide range of manufacturing processes, micro manufacturing, metrology on all scales as well as modeling approaches to all these subjects.

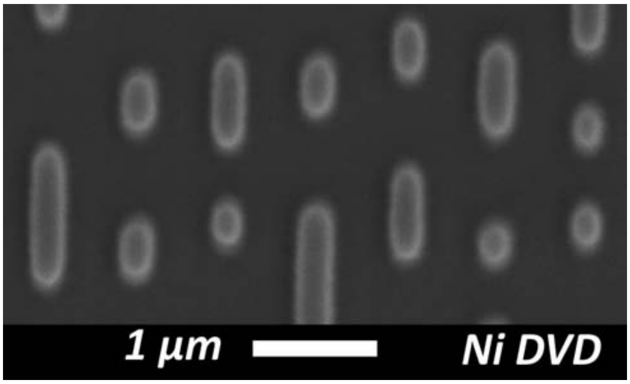
The objective of the research activities of the section is to promote 'Precision Manufacturing' to meet requirements to modern products in terms of high performance, durability and reliability, as well as size and cost efficiency. Research is based on a multi-disciplinary use of process technology, materials science, thermodynamics as well as solid and fluid mechanics in the analysis and modeling of manufacturing processes.

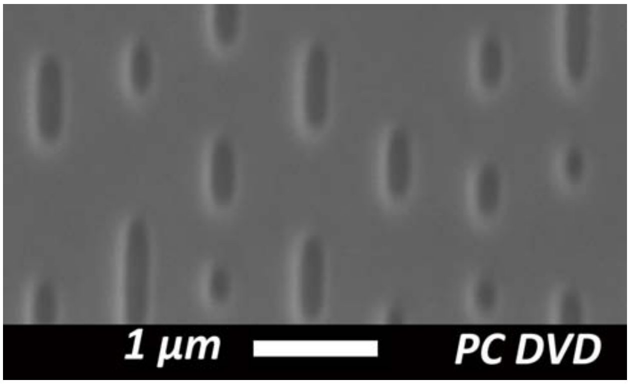
Metal forming and tribology
The metal forming theme focuses on experimental and numerical analysis and modeling of cold forging of steel, stainless steel and aluminium, rolling including skinpass rolling, mechanical processing of superconductors, sheet metal forming including deep drawing, hydroforming and Single Point Incremental Forming (SPIF). Metal forming tribology is focusing on testing and modeling of friction, lubrication and wear in metal forming.

Metal casting
Metal casting of complex and optimized components is another research theme. This area stands on two legs: materials engineering and optimised production methods. The material part is conducted in close collaboration with the MTU section, and the optimisation part in close collaboration with the process modeling group.

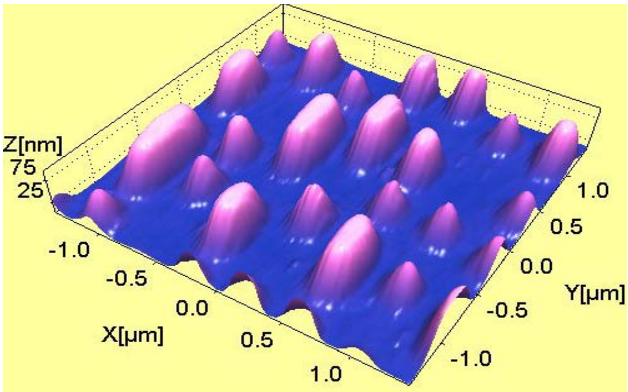
Manufacturing metrology
Geometrical Metrology activities concern development of methods, equipment and artefacts for analyses based on functionality related and traceable measurements of products, manufacturing processes and production equipment. Main research topics are:

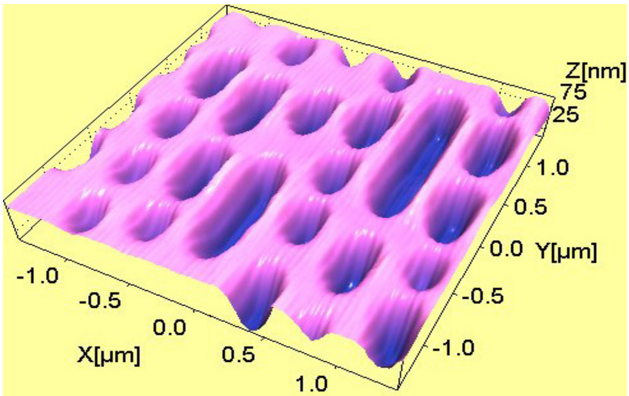
- surface metrology
- coordinate metrology
- process metrology.





Scanning electron Microscope (SEM) for micro/nano manufacturing quality control: inspection of DVD features on SEM images of nickel stamper for DVD optical discs moulding (left) and DVD polycarbonate moulded optical discs (right).





Atomic force microscopy (AFM) for micro/nano manufacturing metrology: inspection of HighDefinition-DVD features on (left) nickel stamper and (right) polymer moulded disc (axis magnifications: X = 1x, Y = 1x, Z = 5x).

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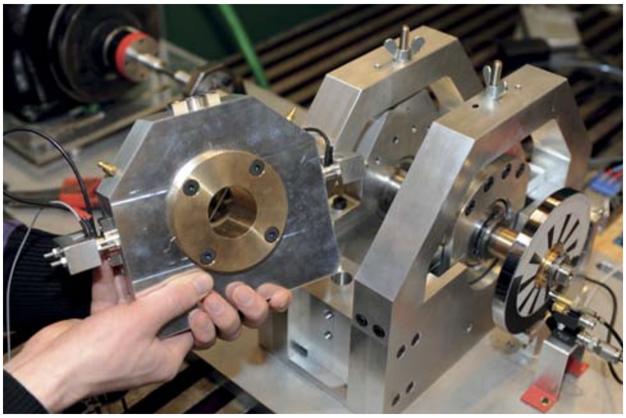
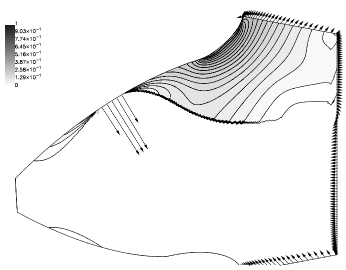
Solid Mechanics

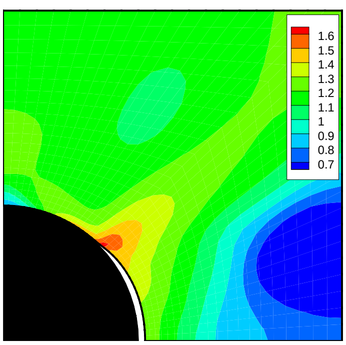
Research activities



Front: *Actively-lubricated gas bearing controlled by piezoelectric actuators.* ***Back:*** *Rotor test rig where the dynamic performance of the actively-lubricated gas bearing is evaluated.*



Full view of asymmetric optimized gear tooth including stress contours.



Contours of the effective stress normalized with the yield stress, for a fiber reinforced metal with advanced fiber-matrix delamination due to transverse loading.

Actively-lubricated gas bearings controlled by piezoelectric actuators (IFS)

Gas lubrication has in recent years witnessed a huge marked development, with applications varying from microturbomachinery to high precision spindles. In order to increase damping and enhance rotordynamic stability active control techniques can be applied to it, leading to 'actively-lubricated gas bearings'. The figure illustrates a prototype designed and built in the section for Solid Mechanics. Such a mechatronic machine component can be successfully designed aided by advanced simulation models based on the integration of several fields of knowledge, including compressible fluid mechanics, machinery dynamics, smart materials and control techniques.

Asymmetric Gear Optimization (NLP)

Large improvements in the bending stress for gears can be found by the use of asymmetric gears and optimization. Using a simple parameterization of the rack cutter we can reduce the bending stress rather significantly. The improvement of the bending stress is in the order of 40% independent of the number of teeth on the gear.

Plasticity Across the Scales (CN, BNL, VIT, KLN, REZA)

In technologies where miniaturisation is central, advantage can be taken by the intrinsic size-effects that have been observed on small length scales in many materials including metals. In the micron to sub-micron range the general tendency that 'smaller is stronger' has been confirmed for a variety of metals under various loading conditions. In order to exploit the small scale behaviour of metals, appropriate material models and numerical models must be developed. In this research project material models accounting for size-effects in materials are developed.

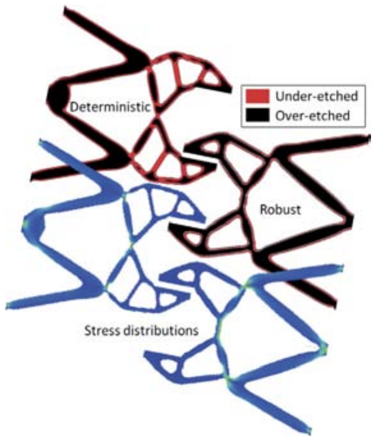
The focus is on fracture mechanisms, thin film delamination and multi-scale reinforced composites. Analysis of

The main research topics at the Section of Solid Mechanics are the mechanics of materials, the strength and dynamics of structural components and multiphysics systems as well as machine elements and mechatronics.

In mechanics of materials the work includes basic development of material models for inelasticity and damage, size effects on material behavior, micromechanics, and applications to fracture mechanics and fatigue. The structural mechanics research covers vibration analyses and advanced design using optimization methods. This research includes computational design of multi physics problems, based on the Finite Element Method and Topology optimization. The machine elements group works on tribology, active vibration damping through magnetic actuators and optimization of machine components.

such systems are complicated by the fact that mechanical properties spanning many length scales, from the nano-scale to the macro-scale, are interacting.

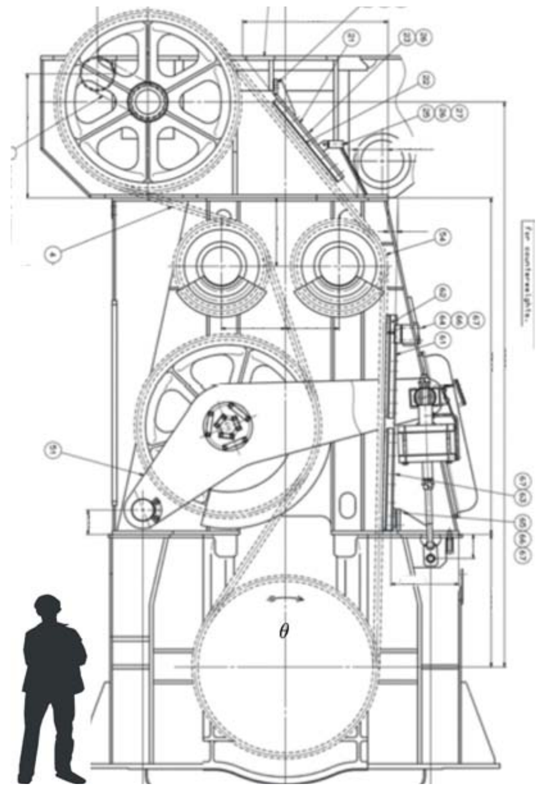
Robust topology optimization of compliant mechanisms
Traditional topology optimization applied to design of MicroElectroMechanical Systems (MEMS) results in mechanisms connected with thin hinges. Such hinges are vulnerable to manufacturing variations like over- and under-etching and have high stress concentrations. Robust designs can be obtained by including the manufacturing uncertainties in the analysis and topology optimization process. Robustly optimized mechanisms have less stress concentrations and are insensitive to production errors.



Compliant gripping mechanisms optimized using standard deterministic (left) and robust approach (right). Stresses (bottom) are seen to smaller and more evenly distributed for the robust design case.

Experimental bifurcation analysis by control-based continuation
Control-based continuation allows for bypassing mathematical models, to systematically explore how vibrations of a mechanical system change with parameters, even tracking unstable vibrations. Using a path-following algorithm to track branches of bifurcation diagrams, the system is guided to desired states by a controller that does not influence the natural dynamics of the system. Currently we explore these ideas for a simple mechanical oscillator with a strong impact nonlinearity.

Roller chain drive dynamics: theoretical modeling and analysis
Roller chain drives are widely applied in engine driven machinery. The discrete nature of roller chains may cause noise and vibration, and introduce complex dynamical behavior. We formulate and analyze simplified theoretical models describing characteristic features of chain drives, focusing on obtaining fundamental insights, and validating against numerical simulation and laboratory experiments.

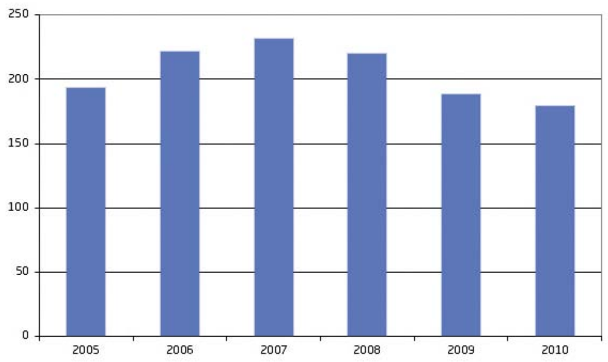


Marine propulsion engine with roller chain drive.

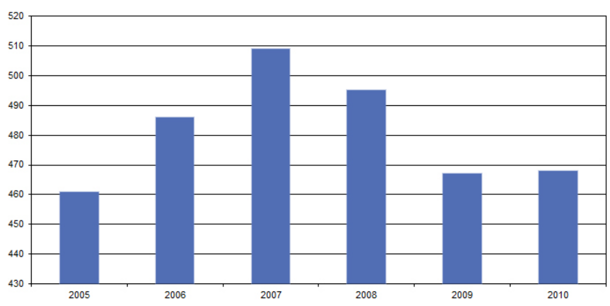
Key Figures

Education and Finances

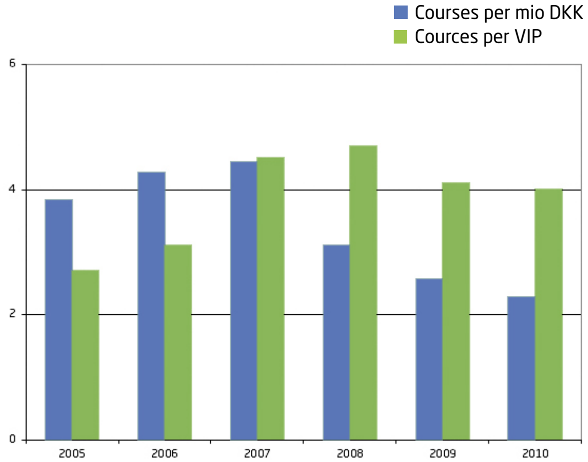
Number of courses



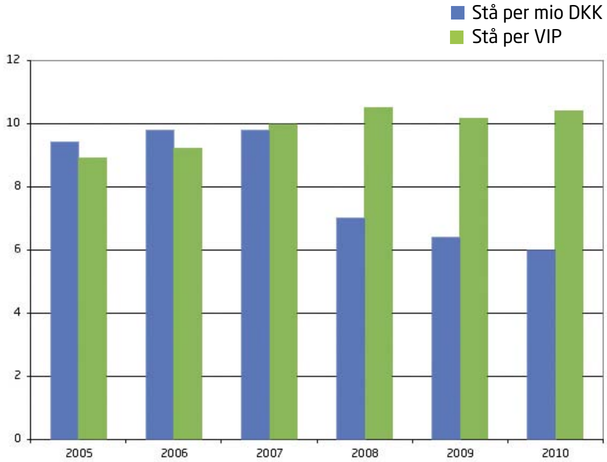
STÅ production



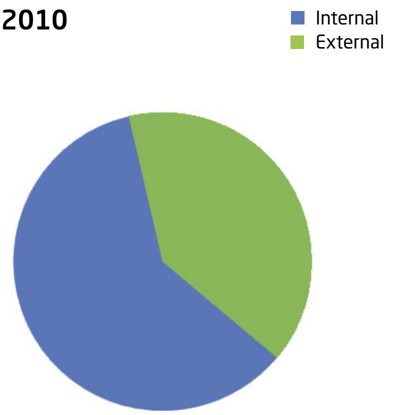
Number of courses per mio DKK & per VIP



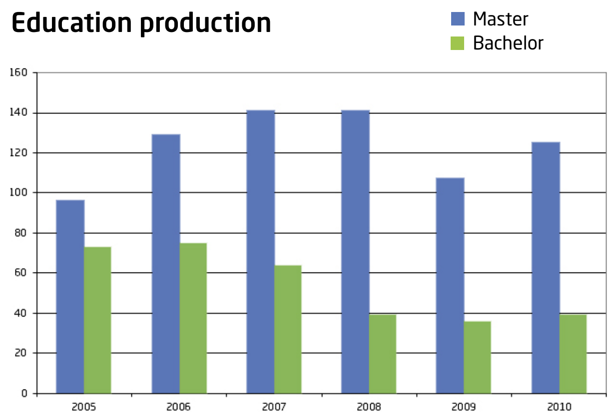
STÅ production per mio DKK & per VIP



Revenue 2010



Education production



Key Figures

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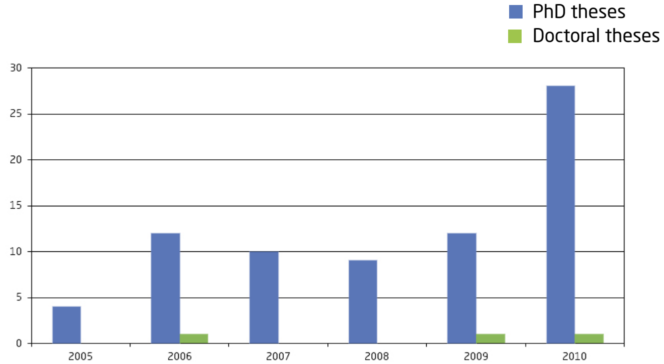

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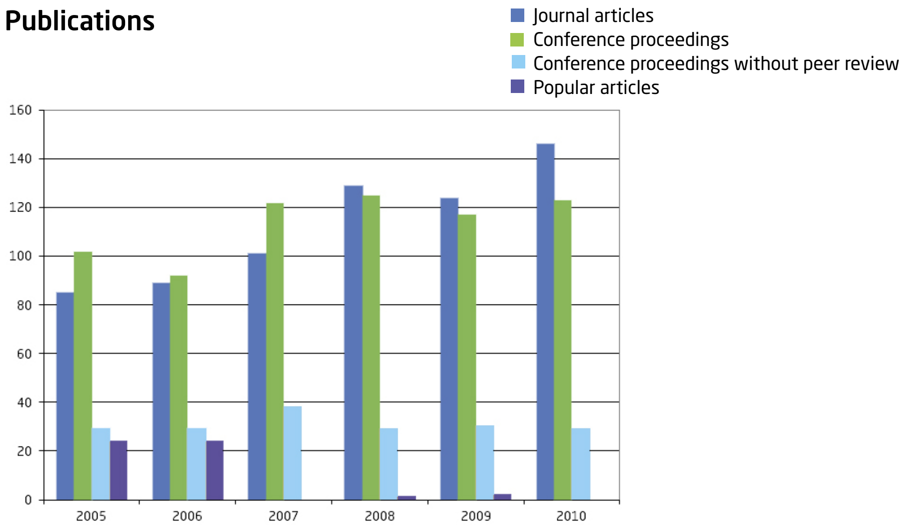

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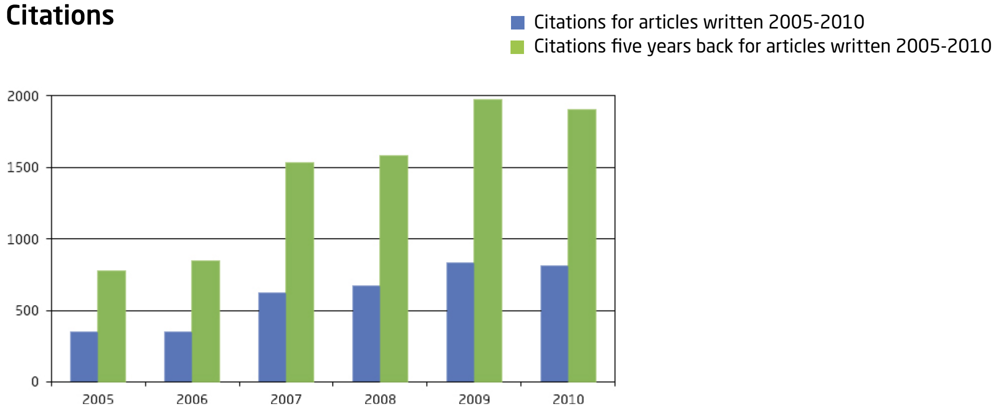

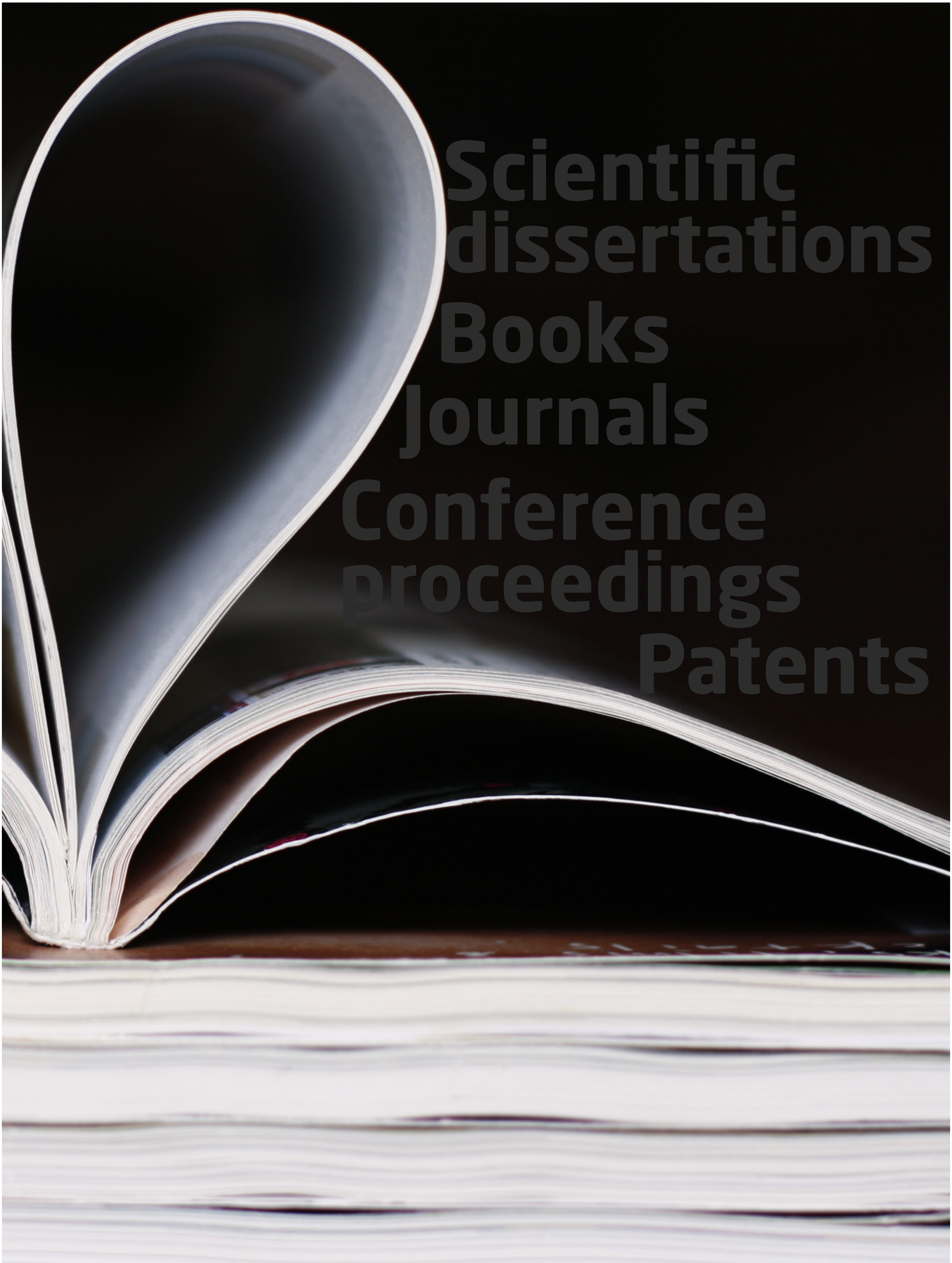
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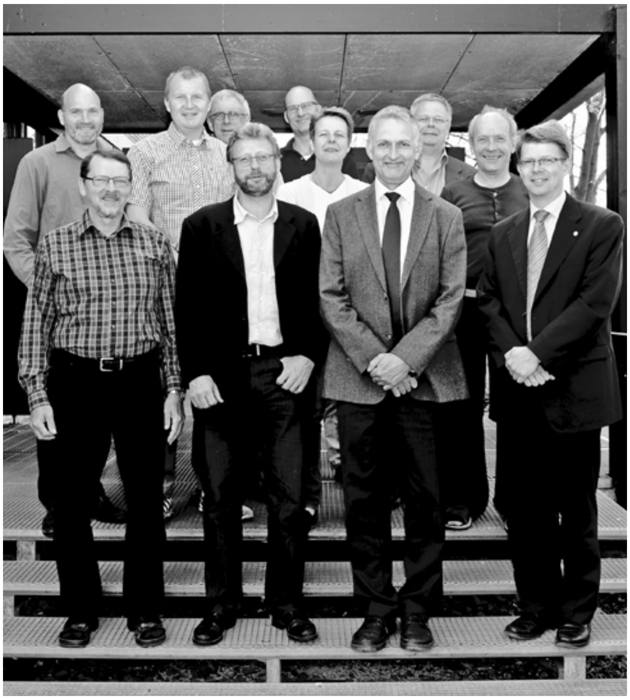

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