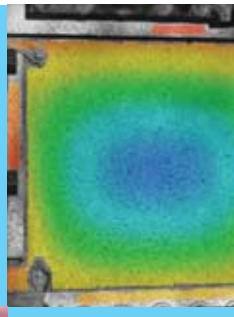
Department of Mechanical Engineering








Technical University of Denmark, DTU

Annual Report 2007

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Foreword

Head of Department

The year 2007 turned out to bring more surprises than expected. The fusion of five public sector research institutes into the Technical University of Denmark, DTU, from 1. January 2007 initiated a reorganisation of the entire new DTU. The reorganisation has also resulted in considerable changes of the Department of Mechanical Engineering, and this is the last annual report from the "old" department.

As a result of the reorganisation, we will from 1. January 2008 say goodbye to two sections, and hello to two new sections. Engineering Design Section will move to DTU Management Engineering and Indoor Environment Section will move to DTU Civil Engineering. The two new sections will be the Materials Science and Engineering Section and the Manufacturing Engineering Section, both coming from DTU Management (former IPL), and we look forward to present their work in the next annual review.

The reorganisation of the departments was prepared in working groups in the spring of 2007 where different possibilities were discussed. In August it was clear that two new groups would come into the department, and representatives from the new groups were invited into the management board from September.

The 31. August was the last working day as director for Prof. Preben Terndrup Pedersen, who has been in charge of the department since the formation in 2001. It has been a very successful time since that. The productivity of the department has improved on all measures.

The key figures on the pages 34-35 show the development in education and research since 2002. Education measured in STÅ (Student years) has increased with more than 50%, and the same is valid for number of publications in ISI indexed proceedings. It was therefore a very successful department that Prof. Preben Terndrup Pedersen handed over to me, as I will function as an interim director until the reorganisation of the department is finished in the spring of 2008.

I wish you an inspiring and pleasant reading of this annual report 2007.

Henrik Carlsen,
Professor, Head of Department

Highlights 2007

Great Victories for DTU Roadrunners

Shell Eco Marathon in France during the 11. - 13. May 2007 ended with two victories for the team DTU Dynamo and a place among the 10 best for the team DTU Innovator. The race attracted a record 257 teams from 20 countries.

DTU Dynamo were two-time winners in the UrbanConcept competition, driving 306 km on one litre of dimethyl ether (DME). Not only did the team come first in the 'Internal Combustion Engines' category for building the best alternative diesel engine, they also won the Climate Friendly UrbanConcept Award for having the car with the least CO_2 emissions.

The hydrogen fuel cell vehicle of DTU Innovator got a 6th place in its class and drove 1617 km on what is equivalent to one liter of normal fuel. Both cars are constructed by students at DTU Mechanical Engineering, under the supervision of associate professor Jesper Schramm.

VKR Foundation Supports Research in Indoor Environment

The Villum Kann Rasmussen foundation has donated DKK 7 mio. for an interdisciplinary research project at the Indoor Environment Section at DTU Mechanical Engineering. The money will be used to investigate the indoor climate of Danish day-care institutions.

The researchers wish to find an explanation for the recent explosive growth in the number of kids with asthma and/or allergies. Previous investigations have shown that there is a connection between indoor environment and the development of asthma and allergies: "We've already done some studies in Sweden and Bulgaria, and we are now looking forward to look closer at the Danish institutions," says associate professor Geo Clausen.

Geo Clausen from the Section for Indoor Environment at DTU Mechanical Engineering will lead the project, with participation by the University Hospital in Odense.

The Villum Kann Rasmussen foundation supports research activities, especially within the technical and natural sciences, agricultural and veterinary sciences and industry research.

The First Civil Engineers in Design & Innovation

On 11. July 2007 DTU got its first civil engineers in the new Master programme for Design & Innovation.

The two students Jonas Rohde Frederiksen (left) and Jais Ask Hansen got top marks for their final project "Udvikling af 'Drop Off' system til blodprøver i forbindelse med blodanalyse" which deals with the development of a Drop Off system for blood tests in relation to blood analysis. With this work they became the first candidates from the DTU Master of Science education in Design & Innovation.

The two students collaborated with the company Radiometer Medical A/S on the development of a component in blood gas analyzer equipment. Jonas' and Jais' project included many stages of a product development process: an initial investigation phase, a concept development phase and finally a risk analysis and construction phase.

Development engineer Henrik Skovsgaard from Radiometer said after the publication of their work, that it had been a good and interesting collaboration, and he thought that the final Radiometer product probably is going to be very close to Jonas' and Jais' results.

Jonas Rohde Frederiksen and Jais Ask Hansen started the Master program for Design & Innovation in 2002. Now, after five years of hard work, they can call themselves the first design engineers from DTU. And the future is already shinning bright. Jonas will start as development engineer at Aasted-Mikroverk, while Jais hopes for a job at Radiometer Medical A/S .

Opening of New Lab Facilities for Students

The opening of the new innovation lab facilities took place in November 2007 in connection with the MEK project event for students being held in the lab.

The biannual MEK project event is popular among students who are invited to meet potential supervisors and discuss their coming bachelor project or master thesis over a sandwich. The lab facilities were established in the former laboratories of building 413 offering equipped boxes for six different groups of students.

The Blue Denmark at Career Fair

The Danish Center for Maritime Technology (DCMT) participated at the DTU DSE Career Fair on the 28. and 29. March 2007 in Lyngby.

Part of the initiative was to look for new business opportunities, partnerships and to provide career opportunities for new engineers.

DCMT is a technological knowledge center collaborating with FORCE Technology and DTU Mechanical Engineering. Its mission is to support research, development and innovation in the maritime sector in Denmark.

"The Blue Denmark", which includes shipping, shipbuilding and offshore engineering and also comprises manufacturers and suppliers of equipment, has witnessed an explosive growth in recent years, and is therefore looking for new engineers with competencies in ship building, energy, IT, environment and project leadership.

In total, The Blue Denmark employs more than 100.000 persons in Denmark, and most of the 200 Danish shipping companies have offices all around the world.

DTU Students Win Essay Competition in the U.S.

If you want to position a company to be one of the high tech, global manufacturing enterprises in the year 2030, which challenges will you have to address if you want to stay competitive in the world market?

The two phd-students Giovanna Vianello and Adrian Tan from DTU Mechanical Engineering answered well to this question, so well that they won an essay competition at the American Society of Mechanical Engineers (ASME) and National Science Foundation (NSF). Their first price gave them the opportunity to attend the 2007 ASME International Design Engineering Technical Conferences in Las Vegas.

Vianello and Tan described in their essay how a company will have to address all the new tasks, changes and challenges in research, technology, operations, services and partnerships, in order to be successful in the global market place.

The Science of making Torque from Wind

Researchers start to agree: Computational Fluid Dynamics (CFD) is now so advanced that it reflects reality. The prospects were discussed at the second TWIND conference in the summer of 2007.

The Fluid Mechanics Section at the Department of Mechanical Engineering organised "The Second Conference on the Science of Making Torque from Wind" in August 2007. The conference quickly sold out, but the organisers managed to create extra seats, allowing more than 160 delegates to take part.

International researchers from academia and representatives from the wind industry travelled to DTU this late august and discussed the most important developments in aerodynamics, aero-elasticity, aero-acoustics, wind conditions and wind farms.

Engineer Erik Miranda from Vestas felt very positive about the fruitful interactions at the conference between industry and academia: "We at Vestas want to know what happens in academic research. It affects us and we depend on a good working relationship with university scientists." And as a member of the European Parliament, Britta Thomsen said: "The Danes have shown, that a country can base a substantial part of its power production on wind without harming its competitive position."

Important developments

When summarising over the conference, the delegates found that Computational Fluid

A group of delegates chose to visit Middelgrunden Offshore Wind Farm just outside the Copenhagen Habour.

Dynamics (CFD) is now so advanced that it "reflects reality". This insight told the participants that the numerical wind tunnel - an almost perfect simulation of the real thing - may soon be possible.

This is a result of immense importance. Researchers will then be able to test very large wind turbines. Now, they have to rely on experiments with models in wind tunnels, leading to a somewhat inaccurate outcome. Improved computer models in for example rotor aerodynamics, aero-elasticity and wind forecasts provide great prospects for optimizing wind turbines.

Amongst other future improvements is the ability to place wind turbines in challenging terrain, such as forests and hilly landscapes. Also, improved wind predictions will provide a greater yield for turbine owners. Knowing how the wind will behave allows owners to sell the electricity in advance, when the price is high. Wind turbines will also be more quiet, as the noise models are now so advanced, that they can be used in the design process.

Read more at www.twind2007.mek.dtu.dk

Invited speakers:

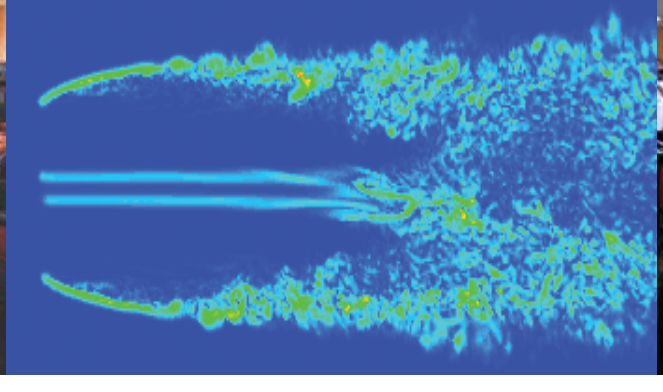
- Bjarne Lundager, Danish Wind Industry Association
- Britta Thomsen, MEP: "A win(d)-win(d) situation for Europe"
- Peter Fuglsang, LM Glasfiber: "The new LM Glasfiber wind tunnel"
- Erik Lundtang Petersen and Ib Troen, Risø; "The making of the wind atlas method: From complex physics to a simple calculation method"
- Henrik Stiesdal, Siemens Wind Power: "Trends in the development of wind turbine technology"
- Herman Snel, ECN: "A brief history of wind turbine aerodynamics: From Betz to Better"

Heard at the conference

"The back edge of wind turbine rotors could be made bendable. This would make them adaptive, more efficient and more durable."

"Practical suggestions to help wind turbines float on the sea."

"Wind turbines on land will probably stay small; the large 5 MW turbines will be placed at sea."



Education

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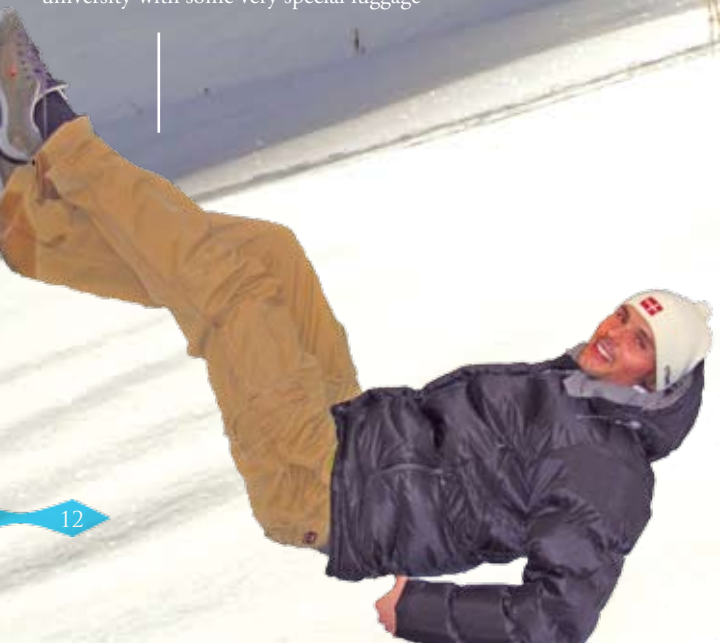
Ditch the Spare Tire

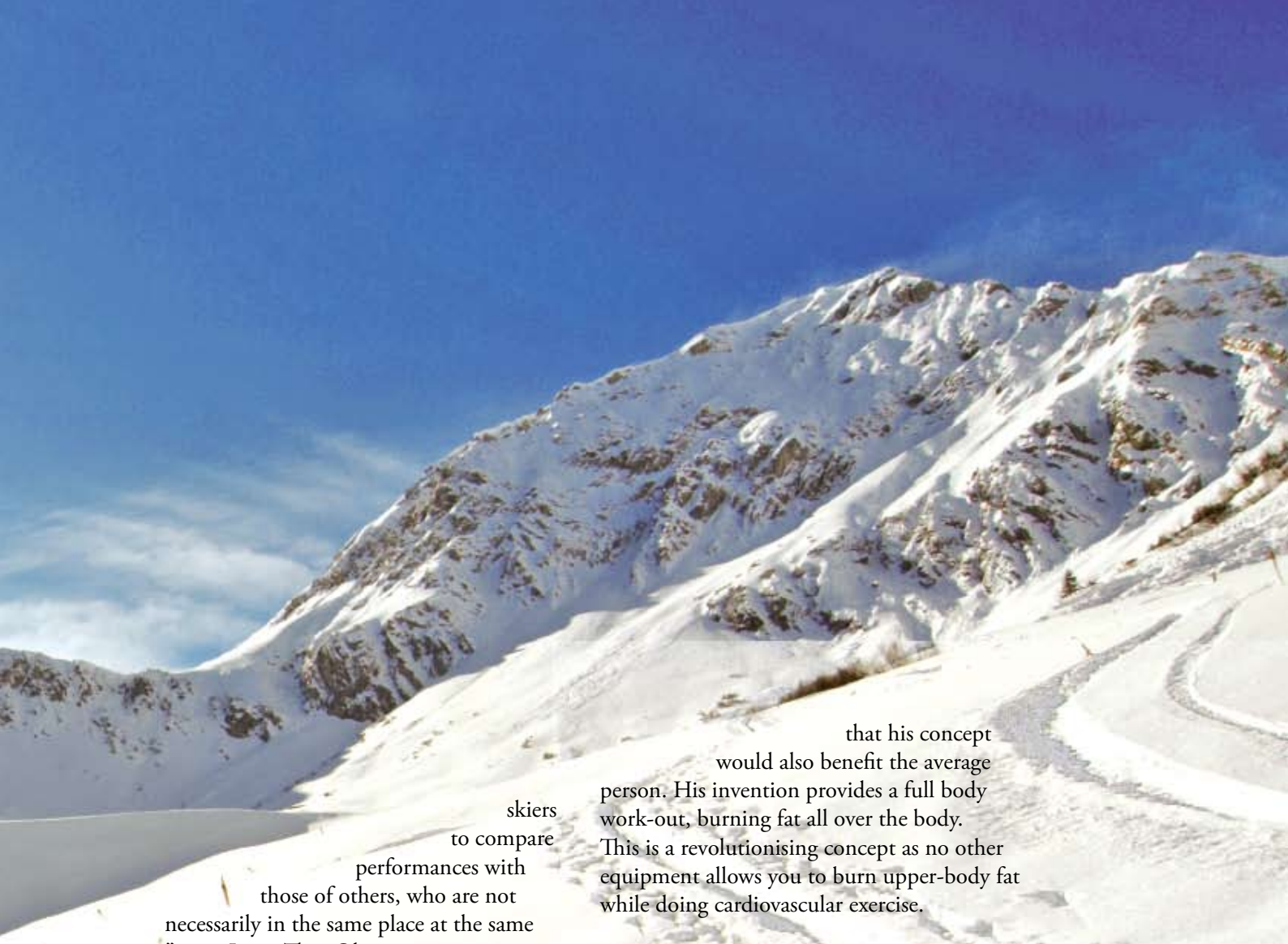
A Professional cross-country skier turns idea into a real life product during final bachelor project

Jonas Thor Olsen has combined his life as a professional cross-country skier with part-time studies at DTU and in December 2007 he was awarded a bachelor degree in Mechanical Engineering – leaving university with some very special luggage



Skiers have a real challenge on their hands when training off-season. No exercise routine makes them to use their muscles as they do when skiing. This makes it difficult to keep the right shape throughout the summer.

But all this may now be a thing of the past. Being an engineering student Jonas Thor Olsen got an idea, which slowly started to develop in his mind. "Besides the problem of summer training, elite skiers also need a way to measure and compare form. The snow, the tracks, the weather and other factors vary greatly, and this affects performance. I wanted to find a way for



skiers to compare performances with those of others, who are not necessarily in the same place at the same time", says Jonas Thor Olsen.

In the Right Spot

Starting work on his bachelor project in June 2007, Jonas jumped at the chance to develop his own brainchild. "I had an idea and I was able to turn it into a product. After less than six months I had a working prototype."

"Being located at the Department of Mechanical Engineering I was in a very privileged situation. I was given the opportunity to collaborate with highly skilled experts and I had access to special facilities and equipment. If you ask me, this could only happen at DTU", says Jonas.

Ditch the Spare Tire

Jonas started out wanting to create fitness equipment for top athletes, but he soon realized that his concept would also benefit the average person. His invention provides a full body work-out, burning fat all over the body. This is a revolutionising concept as no other equipment allows you to burn upper-body fat while doing cardiovascular exercise.

As part of the project Jonas performed user surveys and the equipment was tested by medical professionals, top athletes as well as the man in the street. The results of the surveys were encouraging. The equipment was found to be safe, fun and easy to use.

Developing a new product meant working with materials, dimensioning, physiology and design. "Creating a good design was a challenge. There's no unequivocal solution. You can't measure design as you measure for example the strength of materials. It's a matter of judgment and living up to peoples expectations of what fitness equipment looks like", says the young entrepreneur.

Jonas Thor Olsen hopes the product will hit the shelves in 2008.

Teaching Programme

The Department of Mechanical Engineering (MEK) offers teaching programmes and courses at undergraduate, graduate, and PhD levels. The teaching programme is very comprehensive and covers energy systems, fluid mechanics, material and structural mechanics, engineering design and product development, coastal engineering, naval architecture, and indoor environment. DTU offers three separate teaching programmes in engineering, the 3.5-year Bachelor of Engineering (BEng) programme, the 3-year Bachelor of Science (BSc) programme, and the 2-year Master of Science (MSc) programme. MEK is responsible for a considerable part of the education in mechanical and energy engineering and engineering design.

Design & Innovation Curriculum

The DTU departments MEK and IPL are responsible for most courses in this curriculum established in 2002. This programme has attracted students to DTU who would otherwise have studied elsewhere. The teaching programme for Design & Innovation is now fully implemented and the programme´s first candidates finished their MSc thesis in 2007. The two very first of these candidates carried out their MSc project at MEK in collaboration with industry, and both candidates were already employed in industry as soon as they had finished their thesis.

International Masters Programmes

MEK contributes very actively to three international MSc programmes: "Engineering Design and Applied Mechanics", "Wind Energy", and "Coastal and Maritime Engineering". In 2006 DTU and Technical University Munich (TUM) entered the European University Alliance in Science and Technology – a contract between universities of excellence. One of the two double degree MSc programmes now offered by DTU and TUM for especially qualified engineering students is the MSc in Computational Mechanics. This new double degree programme has been formulated within the framework of the MSc in Engineering Design and Applied Mechanics.

Three major decisions that influenced the MSc in Wind Energy positively were taken in 2007. Firstly, it was decided that from 2008 the specialization in Wind Energy will be one of DTUs five special MSc programmes, meaning that it will continue to receive marketing as a DTU MSc programme. Secondly, grants from the wind turbine industry are now given to highly qualified students from outside EU allowing these students to follow the MSc without having to pay tuition. Thirdly, the merging between DTU and Risø National Laboratory has opened the possibility to offer more specialized courses in wind energy with the help of the very specialized and well renowned scientific staff at Risø National Laboratory. It is expected that approximately 20 international students will follow the MSc in Wind Energy, and, based on experience from the previous years, they are all expected to find a job within the wind energy sector.

Flexible Master Degree in Maritime Technology
In 2007 MEK established a so called Flexible Master programme in "Maritime Technology". The Flexible Master degree is equivalent to one year of full time studies (60 ECTS points), but covers 2 years as the programme is distributed over four semesters. The master programme is intended for full-time technical employees with ship related activities, and the first participants started in September 2007.

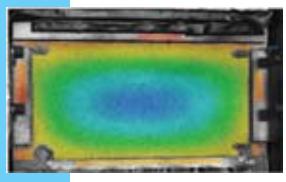
New Lab Facilities for Students
MEK has in 2007 established an innovation lab for students. The facilities give the students the possibility to test their own innovative ideas. The most frequent users of the new facilities are the DTU Eco-car Team, DTU Roadrunners, who in May 2007 again obtained great success at the Shell Eco-marathon in France.

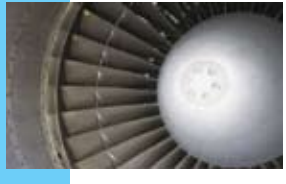
Teaching Methods and Quality
A broad range of teaching methods is employed at MEK, i.e. lessons, classroom teaching, course work, projects, and laboratory experiments. In the BEng programme the CDIO method – conceive, design, implement and operate – is used as teaching method and new study plans with even further focus on CDIO is now being implemented.

All MEK courses are evaluated by students through the DTU teaching intranet. The aim is to further improve the courses. The continuous monitoring of the quality of teaching has proved very fruitful, and new evaluation criteria have in 2007 been decided by DTU in order to put further focus on the teaching quality.

These new evaluation criteria have been implemented in the computer programme used by MEK in order to present the evaluation results graphically and thus allowing a very good overview.

Research & Sections





Digital Deformations

What happens when structures bend and twist and finally fracture? At DTU Mechanical Enigneering specialized Digital Image Correlation (DIC) equipment have been acquired, which is able to accurately measure full-field displacement and strain fields. Ultimately, measurements like these will lead to radical new design configurations in a wide spectrum of applications.

It is important to understand how materials and structures act under straining, so that they can be used to their full potential, taking strength, flexibility and durability into consideration. Measuring deformations is an important aspect of this effort, because it provides insights into structural and material limits.

In addition, an extended knowledge of materials, such as fibre composites, opens up for innovative design solutions. High quality digital experimental data help us to develop and improve numerical models, which, in turn, creates better tools for designing large-scale structures, such as bridges, ships, airplanes, helicopters and wind turbine blades.

The new equipment

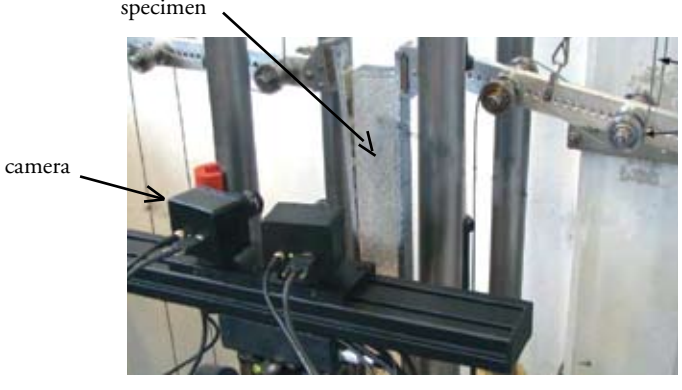
The deformation measurements and analyses are carried out with Digital Image Correlation (DIC) systems with the product name ARAMIS. They have been applied in a significant number of BEng, BSc, MSc and ph.d projects during the recent years and have furthermore been included in a course on experimental mechanics (41811 Experimental Mechanics).

In addition, the DIC systems have been used in several research projects, among those a joint European research project (MARSTRUCT) dealing with maritime structures.

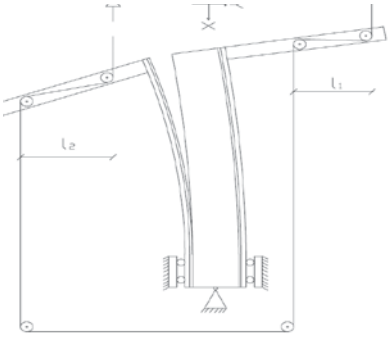
How to measure and what?

With DIC it is possible to measure deformation without touching the specimen, attach strain gauges or using other contact measurement methods. Before carrying out a measurement the specimen is applied a speckled pattern, typically by painting the specimen surface white and subsequently spraying or painting a unique pattern. The specimen is placed in front of two digital cameras, which record the same points simultaneously from two different angles, while overseeing the entire specimen surface. Due to the pattern, each point can be indentified on the pictures from each camera. This gives information of how the pattern has changed, making a deformation analysis possible.

The range of different DIC systems acquired can measure surface displacements in three dimensions and surface strains in two dimensions down to an accuracy of about 0.01% for both



Test rig setup, showing the two cameras and the mounted specimen with painted speckled pattern.



A schematic view of the crack opening in a DCB-UBM fracture specimen.

The consequence of tensional loading on a damaged X-joint specimen. A crack is propagating in the face/core interface resulting in bridging fibres across the crack and permanent decohesion of the face and core layers.

static and high-speed applications (digital image acquisition rates up to 250.000 Hz with the Ultra High-Speed version of ARAMIS). Additionally, the measurement areas range from about 1 cm^2 to 10 m^2, making the systems highly versatile for both small scale material tests to large structural full-scale tests, of for example wind turbine blades. During 2007 the equipment has among other applications been used to investigate the torsional performance and compressive strength of wind turbine blades in a research projects with Risø DTU funded by the Ministry of Energy, Vestas Wind Systems A/S and LM Glasfiber. Furthermore, on the material scale the spreading of interface cracks in polymer sandwich materials has been investigated by use of the DIC systems. (see figure above).

Panels in ships

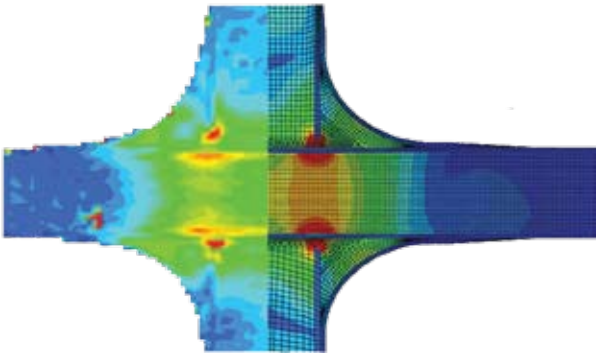
The DIC systems have also been used to investigate the design of sandwich X-joints in naval ships in cooperation with the naval shipyard Kockums (Karlskrona) and DIAB AB in Sweden. Sandwich constructions with face laminates of fibre reinforced plastic have been used in a number of naval ships where low weight has been an important factor. In several cases the superstructure does not cover the full length of the hull, and in some cases also not the full width. In such an arrangement, the end bulkhead of the superstructure is usually attached to the deck in a position lined up with a transverse bulkhead placed underneath the deck. This results in an X-joint configuration with the deck running continuously through the joint and the bulkheads connected to its laminates.

As the hull girder flexes due to motion of the ship in waves, compressive and tensile vertical loadings are exerted alternately on such X-joints. The advanced DIC systems can measure the resulting displacements and surface strains on the X-joint specimen surface edge, depicted on the contour plot below. Combined with a numerical finite element model, important parameters of the X-joint geometries can be studied. These include the core density and thickness, the face thickness and lay-up, and also the overlaminate radius and thickness of the joint.

Consequently, based on these parametric studies, improved design guidelines can be proposed in order to prevent material failure in the sandwich core insert in the X-joint. Additionally, by addressing the face/core interface properties and the density and length of the core insert in the X-joint, improved damage tolerance can be achieved by limiting the propagation of damage at the interface.

For further information, please contact Associate Professor Christian Berggreen at cbe@mek.dtu.dk.

A typical location of X-joints in sandwich naval vessels.



A contour plot, showing the experimental DIC strain measurements (left), and the results of a numerical finite element analysis (right).

Coastal, Maritime and Structural Engineering

The research topics at the Section for Coastal, Maritime and Structural Engineering deal with coastal engineering, maritime engineering, naval architecture, structural engineering and risk and reliability assessment.

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 natural loads, such as waves and wind.

To show the variety of topics treated, a short outline of the current phd and postdoc projects is presented.

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Ongoing phd projects

Cross-shore sediment transport in the surf zone: The description of the cross-shore sediment transport will be coupled with a morphological model to obtain a description of the bar formation and migration under different wave forcing. The major tool is a 3D Navier-Stokes solver with free surface. (Niels Gjøl Jakobsen)

Interaction between seabed and scour protection: Scour protection, especially the hydraulic resistance of flow over beds with large roughness; transport processes at the junction of stone/armour-block layer and the base sediment; and sinking/penetration of stone/armour blocks in the base sediment bed are considered. (Martin Dixen)

Monitoring of ship performance: Onboard measurements will be made and used to develop a method that is based on machine learning and pattern recognition methods. (Benjamin Pjedsted Pedersen)

Decision support systems: Improvement of the onboard prediction of the instantaneous sea state using monitoring of ship motions, metrological data and satellite measurements will be investigated. (Zoran Lajic)

High-efficiency ship propellers: Development of high-efficiency propellers using CFD, taking account of cavitation, inhomogeneous inflow behind the ship, ship-propeller interaction and model to full-scale correction. (Keun Woo Shen)

Propulsion of ship in waves: Emphasis is on the drift forces and added resistance in wave. Two methods are considered for the added resistance: i) the pressure integration method, ii) the momentum conservation method. (Soizic Annick Gabrielle Deschamps)

Optimization of smart composite structures Tailoring composite laminates to use the different coupling mechanisms as a way to passively control the response of composite structures. To be implemented in a structural optimization of wind turbine blades. (José Pedro Blasques)

Damage tolerance of composite materials Test methods for extracting fracture mechanical properties (cohesive laws) from layered composite materials under mixed mode loadings are developed. The main focus is on damage propagation in foam-core sandwich materials. (Christian Lundsgaard-Larsen)

Ongoing postdoc projects

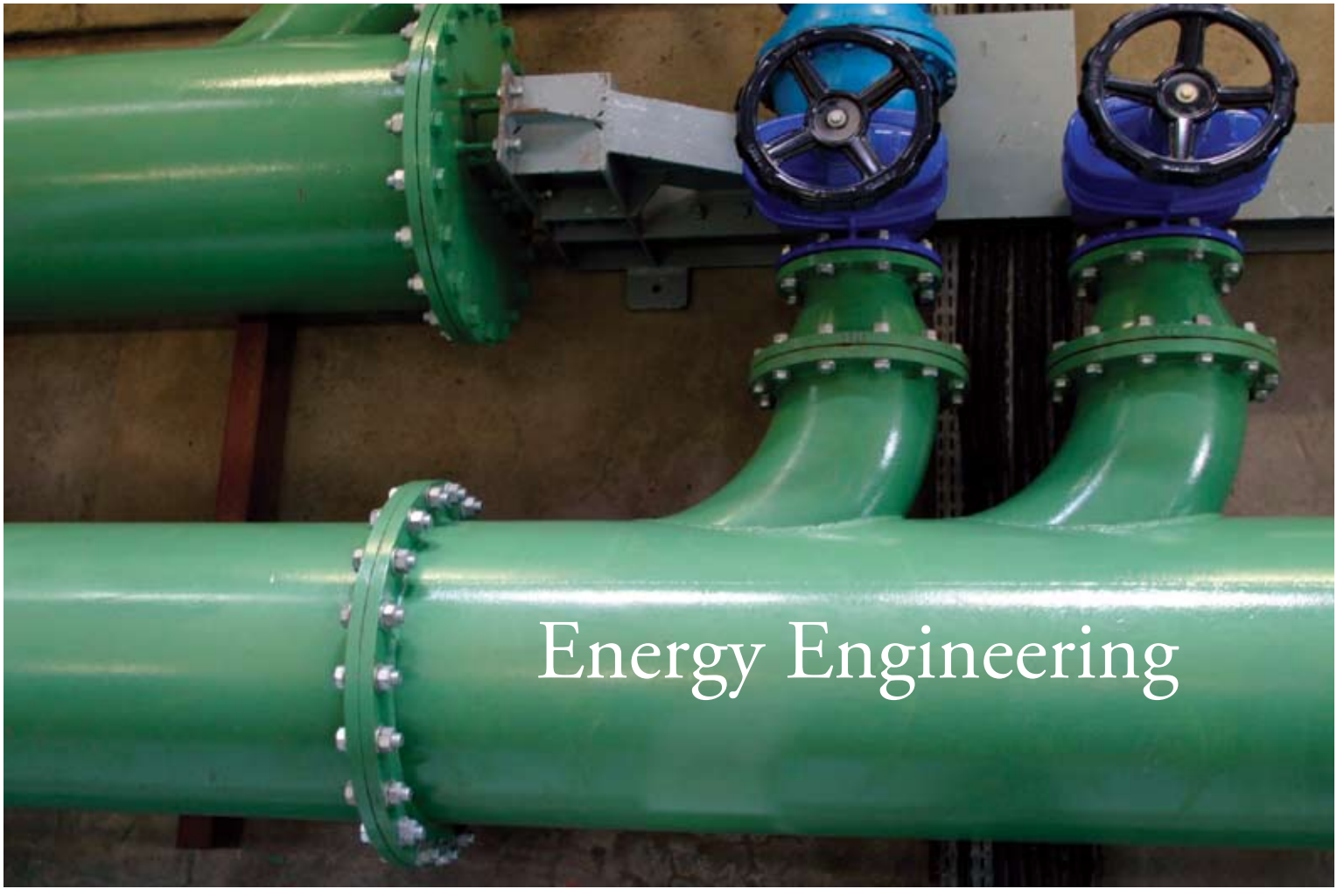
Debond fatigue propagation in sandwich structures: This research project deals with analytical, numerical and experimental debond fracture characterization in sandwich structures subjected to static and cyclic mixed mode loading. The research is highly relevant to e.g. wind turbine blades. (Amilcar Quispitupa)

Dynamic stability of ships: The project deals with prediction of parametrically excited extreme roll responses in stochastic seas. Surge-roll coupling has been recognized as important since the varying encounter frequency affects the resonant condition. (Jelena Vidic-Perunovic)

Solutions to 3D nonlinear water waves problems: Collaborative research are directed toward the development of new efficient state of the art numerical models for better prediction of nonlinear wave motion and phenomena from shallow to deep waters and the interaction with structural bodies. (Allan Engsig-Karup)

Navigational safety in the Baltic area: Risk models and software for calculating collision and grounding risks are developed. (Erik Sonne Ravn)

Wave breaking: Wave overtopping from extreme waves on coastal structures, aerated wave impacts and inclusion of vorticity in Boussinesq-type wave models are considered in a promising concept for wave breaking. (Henrik Bredmose)



Energy Engineering

To improve the department's focus on the most important problems in the modern energy sector the Section Energy Engineering has reorganized. Three new groups have been formed:

- **Section Thermal Energy Systems (at DTU Mekanik)**
- **Group Biomass Gasification (merged with Risø-DTU)**
- **Group Internal Combustion Engines (merged with Section Fluid Mechanics at DTU Mekanik)**

www.et.mek.dtu.dk
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Research activities

The research in thermal energy engineering is divided into six areas:

- Thermal energy systems modelling, simulation and design
- Power production processes: Steam tur bines, gas turbines and fuel cell systems
- Internal and external combustion engines
- Refrigeration and heat pump technology
- Biomass for power and fuel production
- Industrial energy savings

Thermal energy systems and power production are focused on process design and optimization of thermal systems. Analysis of large power plants has been an important activity. New activities include energy optimisation of propulsion systems for large ships, analysis of fuel cell systems, liquid biofuel production, and compressed air electricity storage.

Internal combustion engines have gained increasing attention. The main objectives are investigations of alternative fuels in engines and optimisation of large diesel engines for ships with focus on reductions of fuel consumption and emissions.

Refrigeration activities centre on new refrigerants and process integration in refrigeration systems.

Biomass for power production is mainly concentrated on thermal gasification of biomass and utilisation of gasification gas in IC-engines. Important activities include analysis of wood pellets and pellets production.

In general laboratory experiments, design and manufacture of pilot plants and field tests of existing systems are an important part of the research activities. Especially, the engine lab offers unique engine test facilities including engines from less than 1 kW to 500 kW.

Another general field of research is the development of mathematical models and analytical methods by means of numerical simulation for the analysis of thermal systems and processes, with emphasis on process optimization, energy efficiency, exergy methods, and automatic control.

Current projects

- Refrigerant distribution in evaporators with parallel channels
- Unconventional prime movers for large ships
- Design and optimization of a SOFC based combined heat and power system operated on gasification gas
- Modelling of Benson boilers for optimal flexibility in low load
- Design of Future Integrated Energy Systems
- Compressed Air Electricity Storage

Engineering Design and Product Development

The research area of the section is innovation in product development based on technological insight, market understanding and business development.

This research supports the industry's demand for innovation with systematic methods for improving creativity, costs and quality in the product development process.

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Research activities

The Section of Engineering Design and Product Development is an internationally recognised research unit, founded in 1952, currently in the Mechanical Engineering Department at Denmark's Technical University (DTU). The Section has around 25 employees including 9 PhD-students. In addition to these are 15 full-time industry consultants, employed at Institute of Product Development, who work with the development and dissemination of the Section's tools, methods and theories to industry.

The section's vision is to conduct research and education that raises the quality and innovation in product development. This is achieved through the provision of tools and methods to support the development of innovative products and product/service-systems throughout their lifecycles. Current research includes product architecture, design cognition and knowledge, product/service-systems, sustainable design, conceptualisation, intelligent mechatronics, user-driven design and design automation. Significant research results include contributions to the Theory of Technical Systems, Design for X and Integrated Product Development.

The section's education activities cover mechanical engineering and the founding of a 5-year programme leading to the Master of Engineering in Design & Innovation, which embraces a combination of technical scientific and social scientific topics.

Selected research topics

Design knowledge and cognition
Design synthesis, design expertise, decision-making, engineering knowledge management, and user perception tools for innovation.

Innovation
Challenging and Illuminating Regional Creators and Unfolding Societal Strength (EU-project).

Mechatronics
More intelligent, safer, and more reliable embedded controller design for whole systems, Design optimisation, integration, and mechatronic product development methodology.

Platform-based Product Development
Diagnosis and task-definition for platform projects, synthesis of platforms, documentation and implementation of platforms, and consequences and effects of platforms in product development.

Product Family Architectures
Product family master plan (analysis of product families), modularization and interfaces definition and documentation.

Product Service Systems
Research in product lifecycle modelling, customer activity cycle modelling, and the shift from product development to PSS development, including the implications of a PSS strategy on the product, the product development process, and the environmental implications of PSS.

Industrial Partners

- Aker Kvaerner
- Danfoss
- Grundfos
- Lego
- Maersk Contractors
- Steelcase

Fluid Mechanics

Wake turbulence with a clearly visible wingtip vortex

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.

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Research activities

A gallery of old and new fluid mechanics researchers

Selected research topics

Biological flows
Models for feeding mechanisms of mussels are studied with the Marine Biological Research Center. Fluid transport and ion fluxes in mammalian kidney proximal tubule are developed in collaboration with the August Krogh Institute.

Nanofluidics
Molecular dynamics simulations are used to study transport phenomena at the nanoscale. Recent simulations of gold nanoparticles confined inside carbon nanotubes reveal a phonon assisted thermophoretic motion of the solid gold nanoparticles .

Airfoil aerodynamics
Computing models are developed for analyzing the performance of airfoils with respect to turbulence, laminar-turbulent transition, and rotational effects.

The turbulent free jet
Stereoscopic Particle Image Velocimetry (PIV) and Proper Orthogonal Decomposition (POD) are applied to study the dynamics of the free jet.

Noise and aero-acoustics
Current research on aero-acoustics is focused on the development of high-order schemes and noise generated aerodynamically from airfoils and wind turbine rotors.

Particle-mesh simulations
Particle methods are developed to study nano-, meso- and macroscale fluid dynamics. At the mesoscale, thermal fluctuations may influence the macroscale flow phenomena. Immersed interface techniques for Dissipative Particle Dynamics (DPD) are being developed for the study of flow in complex geometries.

Swirling flows
Swirling flows are studied experimentally and numerically and analyzed using helical vortex theory and bifurcation analysis.

Wind farms
To study the mutual influence of the wakes of turbines grouped in wind farms Large Eddy Simulations are carried out using the actuator line methodology. Further, flows through wind farms, in terms of mean deficit and turbulence inside the wind farm, are modelled with different kinds of models. Model validation is based on real wind farm production data, organized according to inflow sector.

Industrial Partners

- MAN Diesel A/S
- Vestas Wind Systems A/S
- Statkraft
- Siemens Wind Power A/S

Indoor Environment

The interdisciplinary research programme of the Indoor Environment Section aims at developing design criteria and innovative technical solutions for the creation of healthy, comfortable and productive indoor environments that satisfy human requirements at moderate energy consumption.

Many research projects involve exposure of human subjects to single or multiple indoor environment parameters and subsequent observation of the effect on their comfort, health and productivity. Studies take place both in indoor environment chambers, field experiment offices and in buildings in practice.

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Ongoing phd projects

Development of a model to calculate the economic implications of poor indoor climate: The purpose of the project is to establish dose-response relationships between indoor climate factors and productivity, which will lead to models allowing calculation of the expected economical consequences of improving the indoor climate. (Kasper Lynge Jensen)

Occupant behaviour regarding control of indoor environment: The purpose of the project is to study how people control the indoor environment with special focus on indoor air quality and thermal comfort. The project will identify the indoor environmental parameters that are most important for occupant behaviour. (Rune Vinther Andersen)

Airflow interactions in rooms - Convective plumes generated by occupants: Thermal flows generated by office equipment (computers, monitors, etc.) will be less important in the future due to the development of low power consumption devices (LCD screens, halogen lamps, low-energy bulbs, etc.). The objective of the experimental investigations is to study in detail and quantitatively describe the thermal flow above occupants in rooms. (Daria Zukowska)

The effects of exposure to combined indoor environmental factors on human comfort, perceptions and performance of office work: The purpose of the PhD studies is to investigate the impact of exposure to combinations of environmental parameters on human comfort, occurrence of adverse health symptoms, perception of the environment and performance of office work. (Ivana Balazova)

Personalized Ventilation: occupied density and energy performance: The Personalized Ventilation (PV) system aims at supplying clean and cool air at low velocity and turbulence directly at workplaces. PV provides user with control of his/her personal microenvironment. The objectives of the project are to investigate the relations between occupation pattern and PV performance and to quantify the energy consumption of PV. (Stefano Schiavon)

Protection of Occupants from Airborne Infectious Diseases by Advanced Air Distribution Systems: The present study is focused on achieving healthy (infection-free) indoor environment in occupied spaces by developing new technologies for advanced air distribution at workplaces. (Zhecho D. Bolashikov)

Evaluation of the indoor environment in offices based on employee performance: The study focuses on the understanding and development of relationships between the thermal environment in office buildings and employee performance. Possible mechanisms for such effects, including the study of selected biomarkers, will be investigated by subject experiments in the department's climate chambers. (Masaoki Haneda)

Radiant heating and cooling influence on comfort and energy use in buildings: Radiant heating and cooling systems have become popular in the last years, because the manufacturers claim that they can guarantee high quality thermal environment inside buildings. This claim will be critically examined in this project. (Francesco Causone)

The influence of radiant temperature on peoples comfort and control of heating and cooling systems: The purpose of the project is to study the influence and importance of radiant temperature on human thermal comfort and perceived air quality. (Angela Simone)

Effects of Filters, Ventilation and Recirculation rates on Ozone Initiated Chemistry Products in Air-Conditioned Buildings in the Tropics: The project focuses on impacts of filters, ventilation and recirculation rates on the concentration levels and particle size distribution (mass and number) of secondary organic aerosols resulting from ozone initiated chemistry, particularly in the recirculation mode, which is common in air conditioned buildings in the Tropics. (Fadeyi Moshood Olawale)

Solid Mechanics

Main research topics are the mechanics of materials, the strength and dynamics of structural components and systems, machine elements and mechatronics.

In materials mechanics the work includes basic development of material models for inelasticity and damage, size effects on material behaviour, micromechanics, and applications to fracture mechanics and fatigue. The structural mechanics areas include vibration analyses and advanced design using optimisation methods.

The design of multi physics problems, based on the Finite Element Method and topology optimisation, is a major activity. The machine elements group works in tribology and on active vibration damping through magnetic actuators.

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Research activities

Tilting-Pad Thrust Bearings for Heavy Rotating Machines

Selected research topics

Topology optimization for multiphysics problems
New topology optimization schemes are developed for problems that include multiple physical effects. A continuum mechanics based parameterization scheme for electrostatically actuated micro devices has been developed as a part of an Ørsted Postdoc grant.

Utilizing strongly nonlinear HF-vibrations
We explore - theoretically and experimentally - how strong nonlinearity and high-frequency vibrations can be used to dynamically tune the low-frequency properties (e.g. long wave speed) of wave guides (e.g. elastic rods or chains of magnetic particles).

Improving Bending Stress in Gears
In gear teeth the maximum bending stress is controlled by the nominal bending stress and the stress concentration due to the geometric change of the tooth.
The maximum bending stress of the teeth is lowered significantly through redesigning the tip of the cutting tool.

Damage modelling (INNOJoint)
Numerical analysis of damage development in the weld zone of Frictions Stir Welded joints are carried out. The effect of changes in mechanical properties transverse to the weldline is study for transverse loading of the weld.

Thermo-Elasto-Hydrodynamics applied to Bearings of Heavy Rotating Machines

Numerical model based on the Reynolds equation is developed extending the three dimensional thermo-elasto-hydrodynamic (TEHD) analysis of tilting-pad thrust bearings to include the effects of high-pressure injection and recesses in the bearing pads. The model is applied to the analysis of an existing bearing of large dimensions (see figure). Measurements of pressure profiles and oil film thickness are compared to theoretical results when the high-pressure injection is turned off and on. State-of-the-art results are achieved in cooperation with Alstom Power Ltd, Birr, Switzerland.

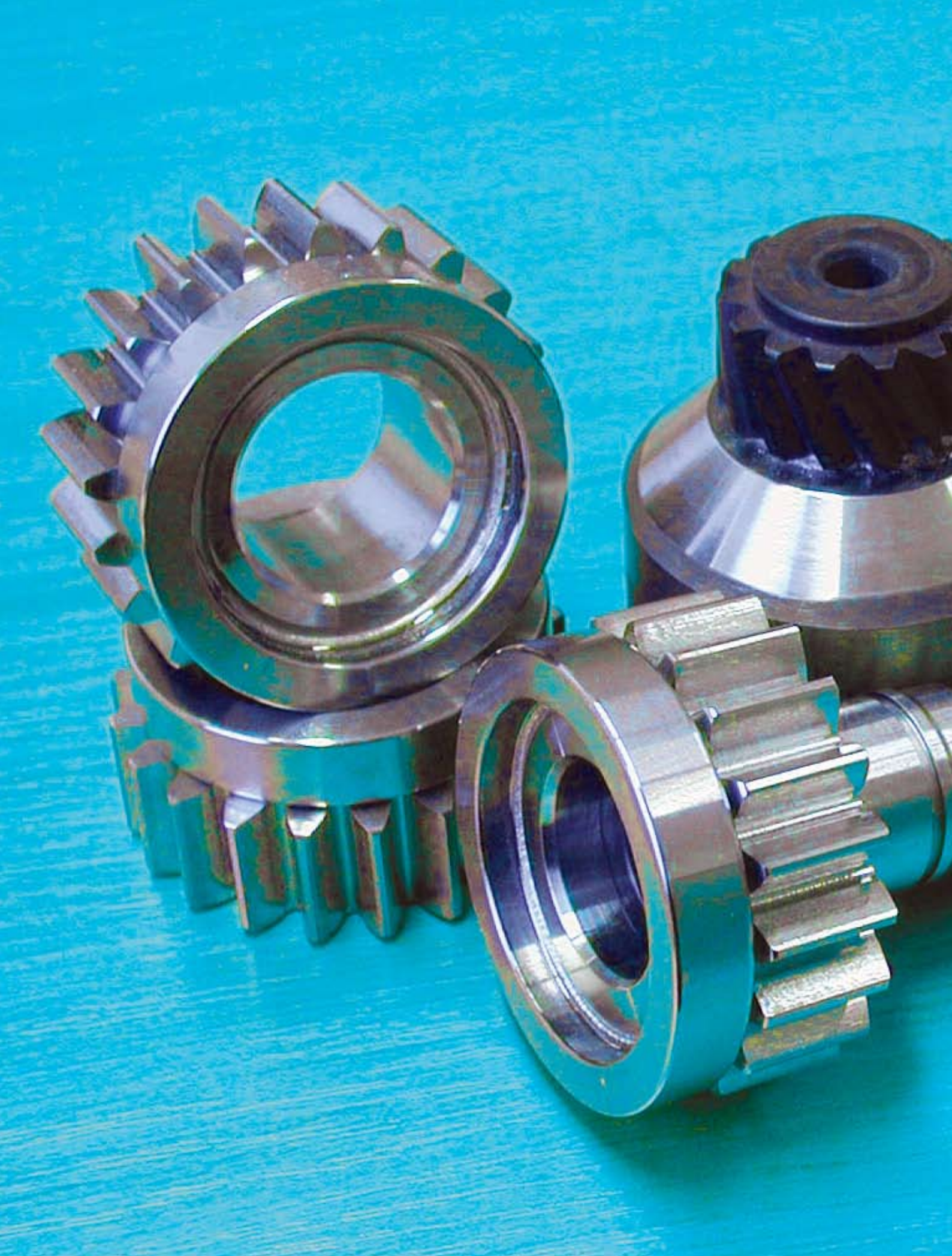
Bulge and neck formation in a polymer tube under internal pressure.

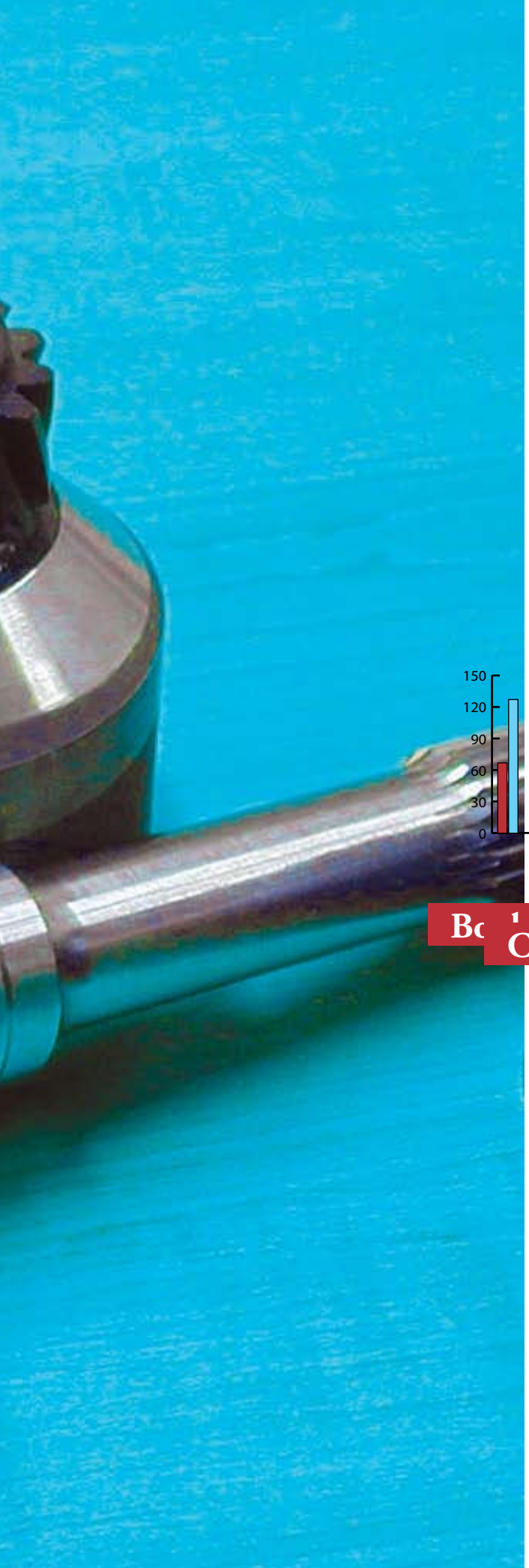
Nonlinear mechanical behaviour of polymers

Experiments and numerical analyses have revealed strongly nonlinear response of polymers. Classical material models developed for describing metal plasticity do not represent the important softening and network hardening effects.

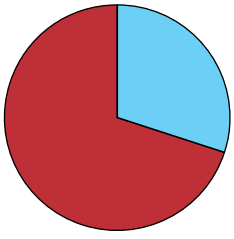
A constitutive material relation including the required nonlinear effects, which is particularly developed to model a thermoplast polymer has been implemented in a large strain finite element program.

Studies of necking, neck propagation and bulge formation in a polymer tube under dynamic expansion have been carried out and high intensity shear zone development between stiff overlapping fiber ends has been analysed as well.





Productivity, Staff & Organization



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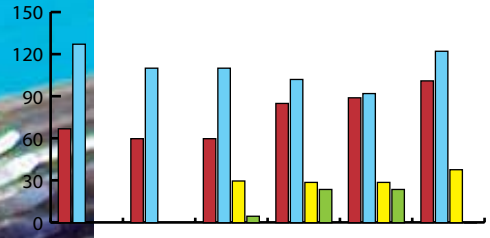

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Saeema Ahmed
Christian Berggreen
Harry Bingham
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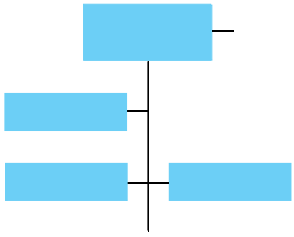

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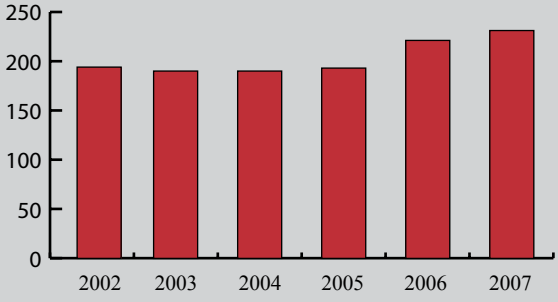
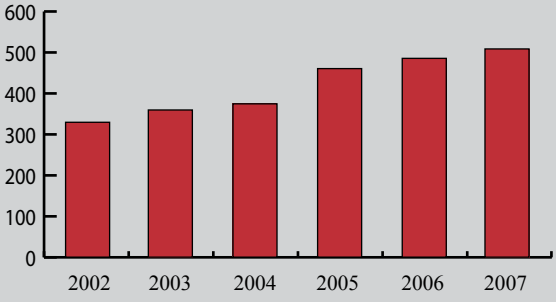
Key Figures: Education & Finances

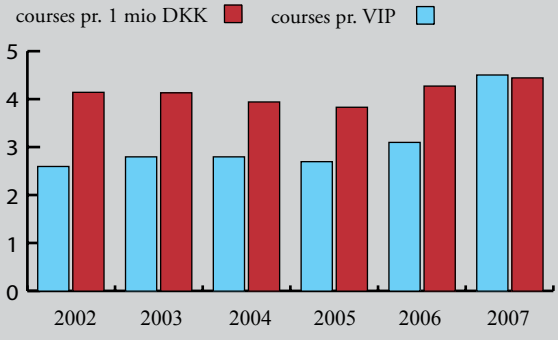
Number of courses



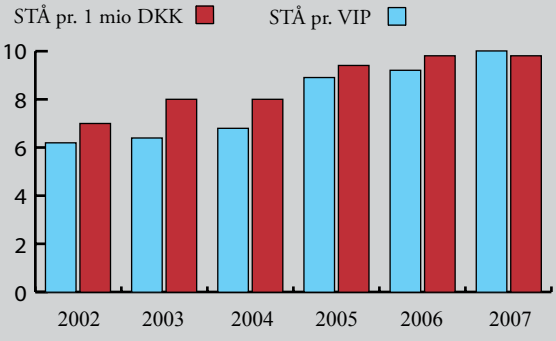
STÅ production



Number of courses per mio DKK & per VIP

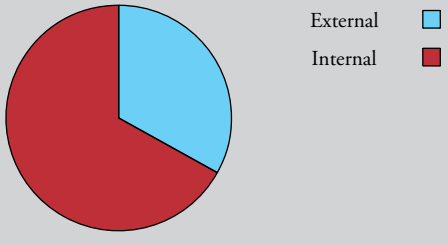


STÅ production per mio DKK & per VIP

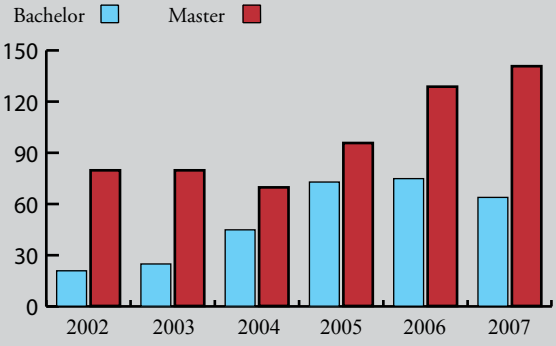


Revenue 2007

(total 108,5 mio DKK)



Education production



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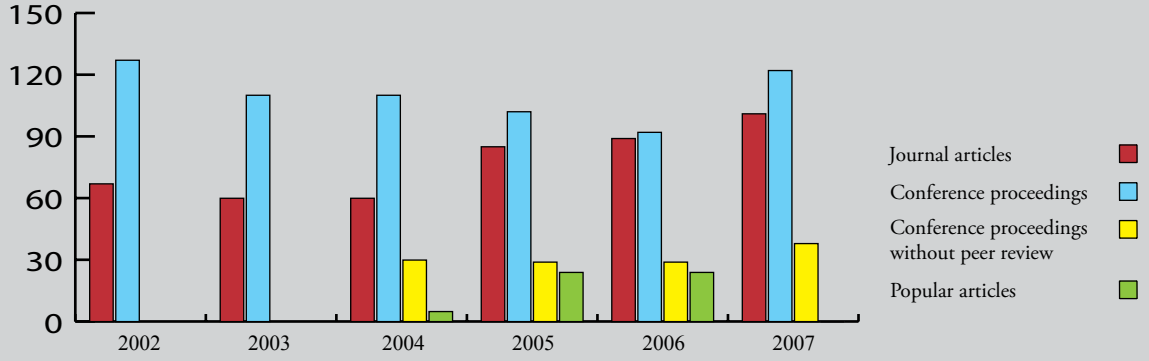
Reseach production

Publications



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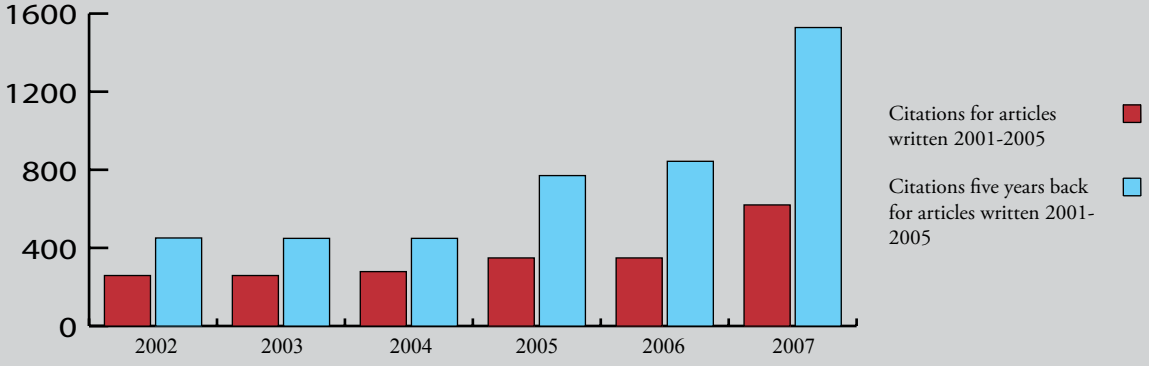

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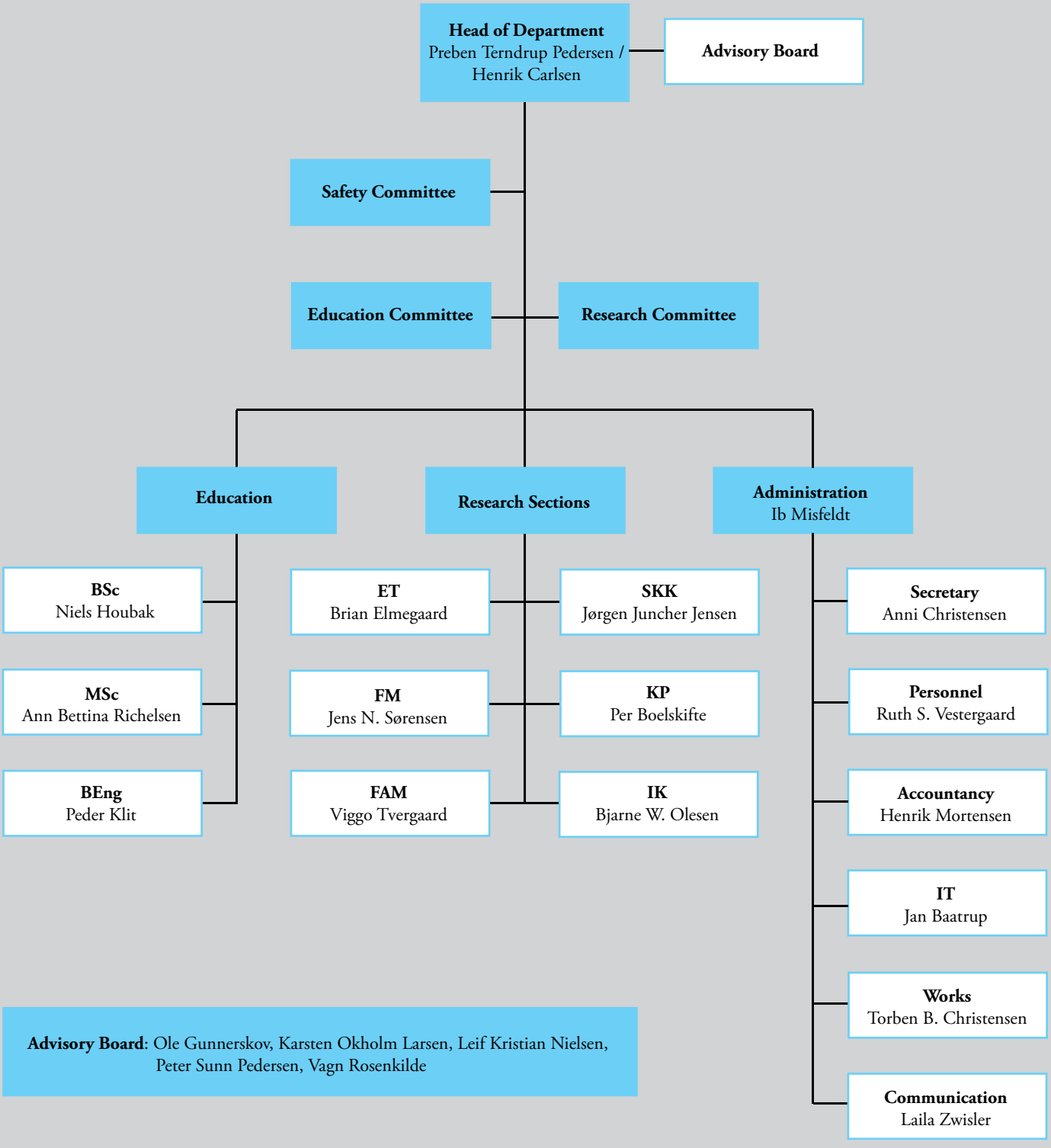

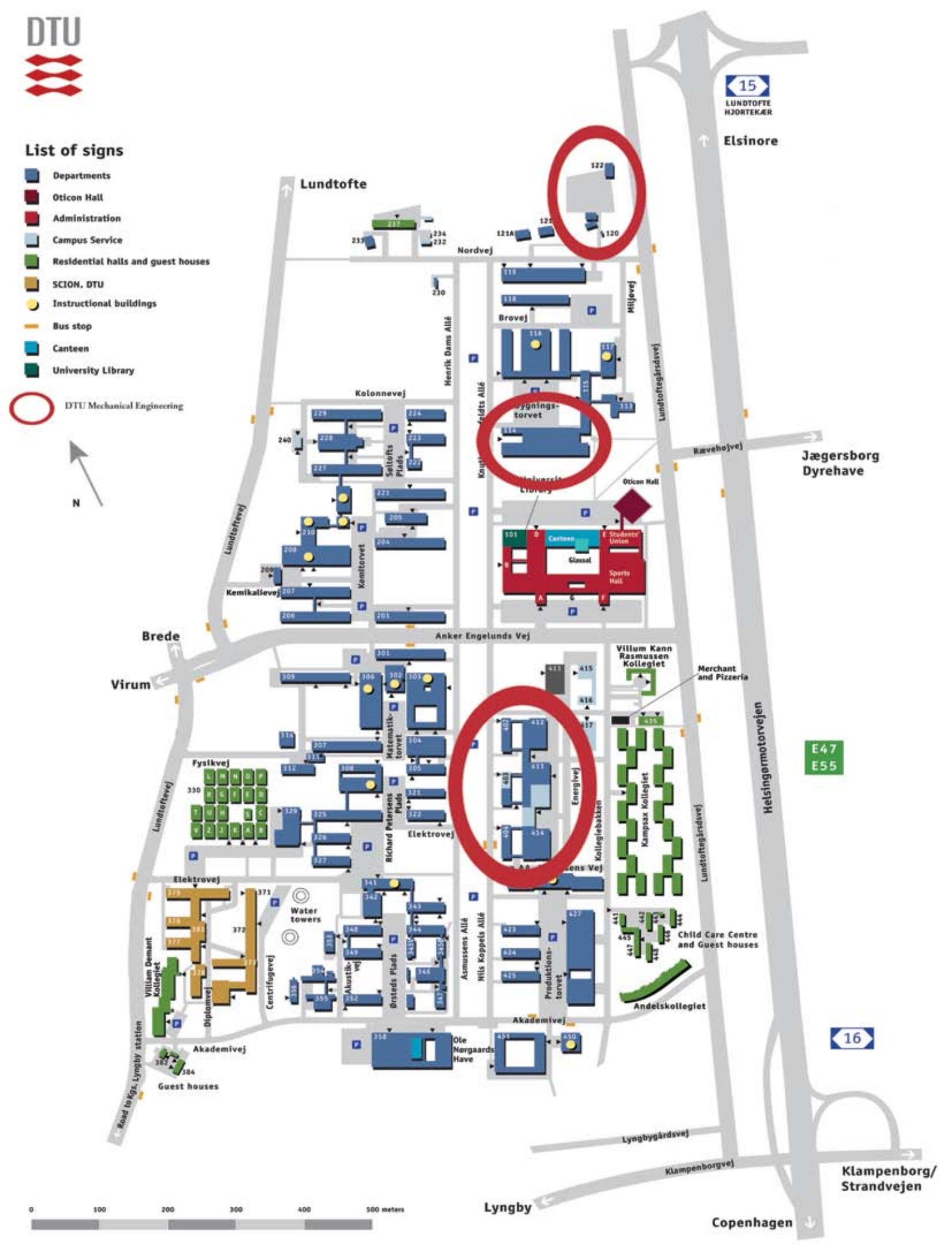
DTU
List of signs
Departments
Oticon Hall
Administration
Campus Service
Residential halls and guest houses
SCION. DTU
Instructional buildings
Bus stop
Canteen
University Library
DTU Mechanical Engineering
N
15
LUNDTOFTE
HJORTEKÆR
Elsinore
Lundtofte
Nordvej
Brovej
Miljevej
Lundtoftegårdsvej
Rævehøjvej
Jægersborg
Dyrehave
Oticon Hall
Canteen
Student Union
Glassal
Sports Hall
Kolonnevej
Henrik Dams Allé
Saltofts Plads
Kemitorvet
Kemikalievej
Lundtoftevej
Anker Engelunds Vej
Brede
Virum
Villum Kann Rasmussen Kollegiet
Merchant and Pizzeria
Matematik-torvet
Fysikvej
Richard Petersens Plads
Elektrovej
Energivej
Kollegiebakken
Kampsax Kollegiet
Helsingørmotorvejen
E47
E55
Water towers
Centrifugevej
Diplomvej
William Demant Kollegiet
Akustik-vej
Asmussens Allé
Nils Koppels Allé
Produktions-torvet
Child Care Centre and Guest houses
Andelskollegiet
Akademivej
Ole Nørgaards Have
Guest houses
Road to Kgs. Lyngby station
16
Lyngbygårdsvej
Klampenborgvej
Klampenborg/
Strandvejen
Lyngby
Copenhagen
0
100
200
300
400
500 meters