Department of Mechanical Engineering

DTU

Annual Report 2006

front page...

Jacob Vester and Katrine Andersen examine the effects of adding ethanol to petrol on particle emissions.

Photo by Bo Jarner

Annual Report 2006

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Contents

Preface

MEK 2006

The year 2006 was the most successful year ever for the Department of Mechanical Engineering (MEK) at DTU.

We achieved our targets for general performance parameters such as number of students, development of new courses and student satisfaction. Our students have once again done well in competitions on new eco-car concepts. The number of journal publications and the number of citations were far above our expectations. To determine if our targets were set at the highest possible levels, we compared the number and impact of our publications with related figures from leading university departments of mechanical engineering in Europe. The comparison confirmed that our achievements are of international standard.

Several researchers at MEK received prestigious international awards for their work, and we have in 2006 received two very advantageous research grants which give us freedom to pursue research excellence within naval architecture and large two-stroke diesel engines.

The main objective of MEK is to conduct teaching and research in mechanics, energy systems and design tools. The Department is responsible for essential parts of the Mechanical Engineering, Civil Engineering, and Design & Innovation curricula of the B.Sc. and M.Sc. programmes at DTU.

The Department of Mechanical Engineering covers the fundamental engineering disciplines within the fields of mechanics, including mechanical properties of materials, strength and vibration analyses of structures, thermodynamics, fluid mechanics, hydraulics, hydrodynamics, safety theory, and control engineering.

Our energy research is centred on efficient exploitation of renewable energy resources such as biomass, wind and waves; efficient energy transformation in combustion engines, energy transport, and energy consumption including refrigeration and indoor environment optimisation.

Within the design and product development areas MEK develops industrial products which take safety, economy, environmental impact, aesthetics and durability into account. MEK attaches great importance to integrated product development and the development of design principles for land-based and marine structures.

This publication highlights some of the achievements during our sixth year of existence.

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Stories from MEK

Knowledge exhange

An International Climate

Every year, MEK has the privilege to welcome a number of researchers from all over the world. Some are here on a short-term visit, while others take up long-term or permanent posts. This traffic facilitates knowledge exchange and creates a stimulating atmosphere.
One 2006 visitor was Professor William Nazaroff from the Civil and Environment Engineering Department at University of California, Berkeley. He chose to spend a three-month sabbatical leave at MEK's Indoor Environment Section, which also constitutes the core of the International Centre for Indoor Environment and Energy.

Photo: Peg Skorpinski

In the summer of 2001 Professor Nazaroff paid his first visit to DTU. "I got a call from the King," he says about an invitation from Professor P. Ole Fanger, who sadly passed away in 2006. "So of course I arranged a visit."
"For my sabbatical leave in 2006, I considered either going to France or returning to Denmark. The pieces for a DTU visit quickly fell into place and so I returned to Denmark. Also, the Section has a strong academic reputation and is well-known internationally," says William Nazaroff.

Chemicals and Humans

"One interesting aspect of my visit was the different approach to research at the Section. My research focuses on pollutants and how their properties lead to human exposures of potential health concern. Here, the emphasis is on human interactions with the environment. Visiting has made me see my own work in a new light," says Nazaroff.
During Professor Nazaroff's sabbatical, US-colleague Charlie Weschler paid one of his regular visits to DTU. "Charlie and I have started a new research project and not only were we able to work on the study while we were both at DTU, but we also found new sources of inspiration here."
The study concerns semivolatile organic compounds, such as phthalates. These chemicals are pervasively present in our indoor environments and they have been detected in the human body. "We wish to find out how they get there. What is it about the properties and the behaviour of these pollutants that lead to them ending up in humans at the levels detected? At DTU I've met scientists who are investigating the connection between human respiratory health and the indoor environment and they were able to offer new insights. Just being there helped me see different things and also see the same things differently. With your eyes and ears open, you can pick up important knowledge indirectly from casual conversations in hallways".

A Pragmatic Approach

The Professor also took note of the different organisational structure of the Section. "It

Semivolatile organic compounds

These compounds are common indoors. They are present in many products or they are formed during processes which occur in homes or workplaces.
The chemicals can slowly evaporate from their source and then migrate throughout the indoor environment, eventually ending up in the human body.
Sources may be pesticides, flame retardants, plasticisers and wood preservatives. The health effects of the compounds are still little known.

Healthy indoor environment

Avoid combustion: Candles, fireplaces and smoking pollute the air in homes.

Manage moisture: If you see mould, you have a moisture problem. Control moisture sources and make sure you have adequate ventilation.

Control sources of pollution: Be aware that almost every product brought into the home can be a source of pollutant exposure. Seek out products that minimise their indoor pollution impact. Avoid controlling persistent odours with scented products — eliminate the source of the odour. Do not store hazardous materials in occupied spaces.

is very different from my workplace. Here you have a strong leadership and everybody pulls together. At Berkeley the head position of any academic unit is a rotating post and each faculty member has their own group. This means that the MEK Section more easily can respond to big challenges. At Berkeley, we have many strengths to play on and every faculty member is a leader, but we are less able to respond in a coordinated fashion," he says. "Also the Section has a more pragmatic approach to their research and is consciously working towards applying knowledge. My own emphasis is on more fundamental research. I have stopped worrying about whether or not my results are applied in the near term. I am patient."

Wife Lives to Travel

During his visit professor Nazaroff assumed the role of a consultant. "I had many meetings with DTU doctoral students, who were either in the process of writing up a thesis or writing an article. I also gave some lectures and helped students interpret experimental results. I also found time to relax and rethink the direction of my career. I feel refreshed." Professor Nazaroff received an Otto Mønsted guest professorship that helped support the sabbatical. "Housing was easily arranged. Through the University we got a nice flat about 2 km from the campus. The flat was in a great area on the edge of a large park – Dyrehaven – and close to interesting sites to bike and walk. My wife lives to travel and she found plenty to do during our stay," he says.

Decision Makers Make Housing Healthy

Professor Nazaroff has three suggestions for residents who wish to improve their home environment. "They should avoid combustion, manage moisture and control pollutant sources. But there is only so much the homeowners can do. Improving indoor environments also depends on government agencies, industry and builders. They can make changes that matter and, at present, they are not doing enough."

"My visit has enriched me professionally. DTU is a very intellectually stimulating and welcoming place."

William Nazaroff took these photos in Dyrehaven

Signing the research agreement at MAN Diesel A/S - DTU Rector Lars Pallesen, Member of MAN Diesel Executive Board Peter Sunn Pedersen and MEK Associate Professor Jesper Schramm
Photo: Peter Hoffmann

MOTOR:
Collaboration Makes Diesel Engines Environmentally Friendly

At MEK world leading academic experts and industry partners work together.

Corporate stakeholders utilize the specialized knowledge and facilities at MEK.

Here are two examples of how MEK and major companies are turning diesel engines into a greener option.

TWO-stroke diesels:
More power, less emission and lower fuel consumption

MAN Diesel A/S

It is simple, large ships have large engines using large quantities of fuel. However, constant efforts are made to improve the engines and reduce fuel consumption. In 2006 MAN Diesel A/S – the world's largest supplier of big two-stroke diesel engines - and Section for Energy Engineering at MEK entered into a research agreement, which aims at further improving the very efficient large two-stroke engines.
"The most sustainable way of transporting goods is by ship. However, due to globalisation the cargo volume is increasing and a lot of heavy fuel oil is used to move all these goods. More efficient ship engines would substantially reduce CO2-emission and air pollution as well as lower fuel costs for freight companies," says Professor Preben Terndrup Pedersen, Head of MEK.

Future-proof

Funding from Man Diesel allowed Energy Engineering to recruit one scientist and three Ph.D. students to work on various projects. The Head of Energy Engineering looks forward to the close collaboration with MAN Diesel. "We are exploring the potential for improvement in performance over the next ten to twenty years. This will help to future-proof development of two-stroke diesel engines," says Professor Henrik Carlsen. "We are a research establishment with a theoretical

Photos: MAN Diesel A/S

A two-stroke engine

Projects:

Project 1: Focusing on the swirling flow field with spray combustion inside the combustion chamber.

Projects 2 and 3: Focusing on boundary layer phenomena like heat transfer and sulphuric acid formation near the walls of the combustion chamber.

Project 4: Focusing on the characterisation of the particulate emissions in order to understand the formation of particulate matter inside the combustion chamber.

outlook and MAN Diesel is a high-tech company, which turns advanced research into real products. This is a really exciting prospect."

The funding was awarded within the framework of the Danish Centre for Maritime Technology and FIST - the Danish Agency for Science, Technology and Innovation.

Danish Centre for Maritime Technology

Funding from Den Danske Maritime Fond allowed MEK and the industrial partner FORCE Technology to form the Danish Centre for Maritime Technology in 2006.

The focus of the centre is on research and recruitment for the Danish maritime sector. Environmental sustainability, safety and efficiency will be the main research areas.

"The Danish maritime industry needs knowledge to stay at the top of its game," says Professor Preben Terndrup Pedersen, Head of MEK.

Cleaner air with particulate filter catalysts

A range of particles results from the combustion process in an engine. Some of these impurities are considered harmful for both humans and the environment.

A catalyst removes diesel soot and reduces the emission of nitrogen dioxide, hydrocarbons and carbon monoxide.

Photo: Scanpix/Corbis/Svenja-Foto

Reality check:
The filters are tested on taxies

FOUR-stroke: Haldor Topsøe A/S and the next generation diesel filter catalysts

When catalyst and technology company Haldor Topsøe A/S began an ambitious project - developing the next generation particulate filter catalysts for diesel cars - they needed facilities to test ideas on engines.
"We do lab experiments with the catalysts, but we cannot reproduce the physical and chemical properties of the particles produced by an actual running engine in our laboratory. It is essential for us to demonstrate and perform measurements of the catalysed filters on real cars in order to get the car manufactures interested in the new technology. We have approached MEK because they own the right equipment," says Keld Johansen, Project Manager at Topsøe. "Using the equipment at MEK is very helpful in the initial stages. We needed MEK's engine expertise for the tests. We also needed to establish if the project was technically and commercially promising before investing in expensive testing gear at Topsøe."

New Knowledge

MEK reaps a number of benefits from the collaboration. "It is not just the funding. This is an opportunity for us to test our equipment and compare our measurements to other findings. The company brought in a number of cars from different makers and we now have measurements, which provide information about the combustion process in different cars," says MEK Associate Professor Jesper Schramm, Section of Energy Engineering, who also looks forward to a joint publication in 2007.

A Product in the Pipeline

The outcome of the testing at MEK has enabled Topsøe to take the process one step further. The new catalysed diesel filters have been fitted on taxies and are now tested on the road – the ultimate test of durability.
"We still have important tests to do, but we are on the verge of having a commercial product. We have promising data from the taxies and we are in the process of patenting the new technology. But I cannot reveal any more," grins Keld Johansen.

Haldor Topsøe A/S

Research

Major activities

Engineering Design Section

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The dominant object of research of the Section is synthesis activities such as product development, construction, project work and problem solving in Product Design and Engineering Design activities. Other areas of expertise include organising, knowledge management, industrial design, interaction design and general theory of technical systems. Our continuous dialogue and collaboration with industry play an essential role in this work.
The Section participates actively in a number of international conferences and workshops. We attach a great deal of significance to feedback, inspiration and broadening of our network at such events.
The Section holds the chair of the Ecodesign Special Interest Group (SIG) under the international research organisation, the Design Society.

Status of cipu Activities

The Section plays a leading role in the establishment of a centre for innovation in product development, cipu. The centre is in the process of creating a network of industrial and academic stakeholders through workshops and conferences. The workshops have been a success, with over 500 delegates attending in total.
A research school in Design & Innovation has been established, which is affiliated to cipu. We are currently seeking further industrial, organisational and research funding for the centre.

Selected Research Topics

Product families based upon architecture

The related Ph.D. projects are based on the assignment of a series of new concepts, which support the description of product families' structural and common building principles, together with approaches for which product variance can be managed. The new language created in this project has been applied on a large scale in connection with the rationalisation of product development at B&O, Vestas, Alfa Laval, Lego, Danfoss and York Refrigeration.

Mechatronic product development

We are boosting our activities in this crossdisciplinary field: The Section participates in two EU proposals -Serpentine Autonomous Fire Extinguishing Robot and Development of a Centre of Excellence for Mechatronics. We collaborate

with Aalborg University on “Intelligent Control of Multi-Body Systems”. Proposals have been put forward in the area of cognition and design automation. The Mechatronic Association, Copenhagen, organised the International Workshop “Mechatronic Day 2006” and the International Seminar on Mechatronics at DTU.

Conceptualisation of oil drilling ships

This project deals with method development for the conceptualisation of oil drilling vessels. The conceptual work is initiated by modelling all drilling activities and equipment activities, together with their time-related and spatial relations, after which the functional units and their structural arrangements are decided.
It has been possible to create architectural patterns in these models, so that experiences and reuse can be built into the conceptual work. This research is carried out in collaboration with Kvaerner A/S.

Staging of conceptualisation

Conceptualisation may be seen as the core activity of innovation: the concept may be the new idea, the new initiative, the new organisation or the new approach, which carries innovation. The aim of this research theme is to develop a multisided, dynamic, and explorative view of conceptualisation.
Our researchers are developing an ontology of design situation dimensions and formulating a number of innovation-oriented questions for the project leader and design team to consider in order to determine a suitable starting point and a new and innovative approach to ideation.

Status of design and innovation activities

The Masters programme of the Design & Innovation educational programme is almost finalized. In the autumn of 2007 the very first Design & Innovation students will graduate.

The Masters programme was created by staff from Department of Manufacturing Engineering and Management (IPL) and MEK.

The collaboration has created a synergy between the synthesis activities and the socio-technical modelling of products, systems and strategies, which in turn has resulted in a renewal of the research-oriented goals of both groups. The Section plays a major role in these activities.

Design & Innovation students and Per Boelskifte, director of studies for the Bachelor programme and head of section in 2007.

Solid Mechanics Section

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Main research topics are the mechanics of materials, the strength and dynamics of structural components and systems as well as 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 research covers vibration analyses and advanced design using optimisation methods.
The design of multi physics problems, based on the Finite Element Method and topology optimisation, is also a major activity. Tribology and active vibration damping through magnetic actuators are covered by the machine elements group.

Selected Research Topics

Through-thickness reinforced laminates

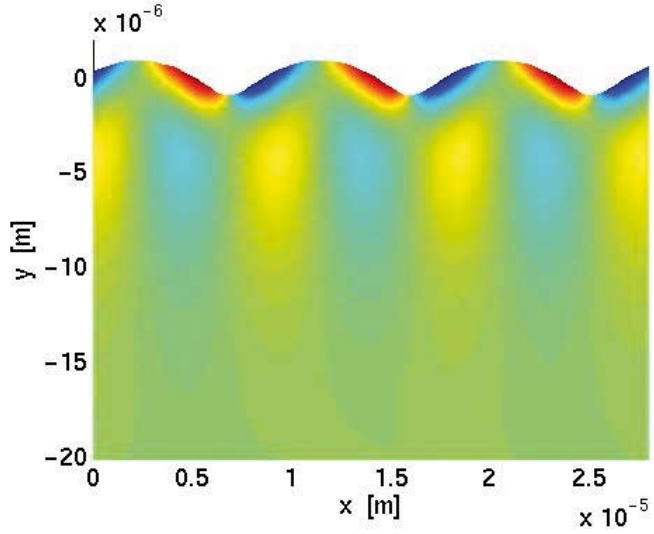
Elasto-plastic numerical analyses of debonding, frictional sliding and pull-out of through-thickness reinforcements in laminates are carried out and results are compared with experiments.

Optimisation of bolt-plate assemblies

Through redesign of bolt and plate prestress contact, the bolts are optimised with respect to fatigue.
The design changes the stiffness of the assembly and large improvements are obtained.

4-D Materials & Structures

Explores what happens to the effective (i.e. averaged / homogenised) properties of a material or structure whose local properties are modulated in both space and time - i.e. in “four dimensions”/4-D - and how this could possibly be utilised.



Topology Optimisation of Surface Acoustic Wave Devices

This DTU funded Ph.D. project is concerned with simulation of surface acoustic waves (SAW). These are elastic vibrations which propagate along a material surface and are extensively used in electromechanical filters and resonators in telecommunication. Topology optimisation is employed to find optimised structures that can focus or guide the SAWs as well as structures that can be utilised for optimal interaction and modulation of optical waves in wave guides.

Piston Ring Friction

In theoretical analysis of piston ring lubrication it is normally assumed that it operates under fully flooded conditions. This is not the case in real life operation. To describe the frictional behaviour of a piston ring correctly the amount and distribution of the lubricant is crucial. This forms the basis for an experimental and theoretical investigation in collaboration with MAN Diesel A/S.

Size-effects in metals

Strain gradient plasticity models are used to model size-effects in porous materials. Comparisons to discrete dislocation calculations have given an estimate of the characteristic length scale in metals. [78], [218]

Optimisation of dynamic systems using Pade approximants

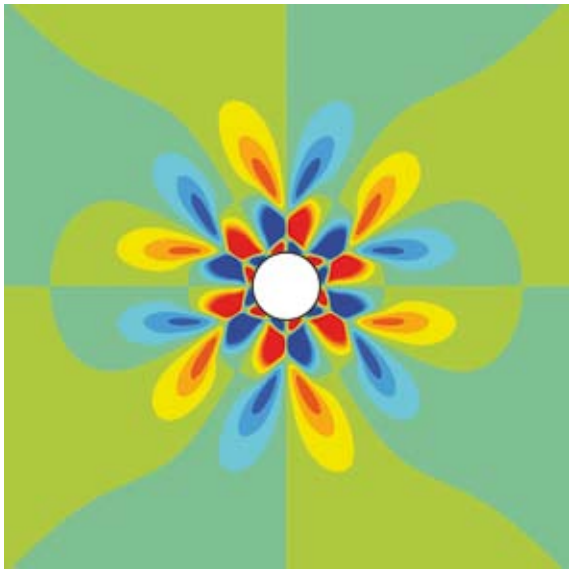
A new fast method is developed for optimisation of steady-state dynamics in finite-size frequency intervals. The dynamic response is approximated with a Pade expansion and design sensitivities are computed with the adjoint method.

Strain gradient crystal plasticity

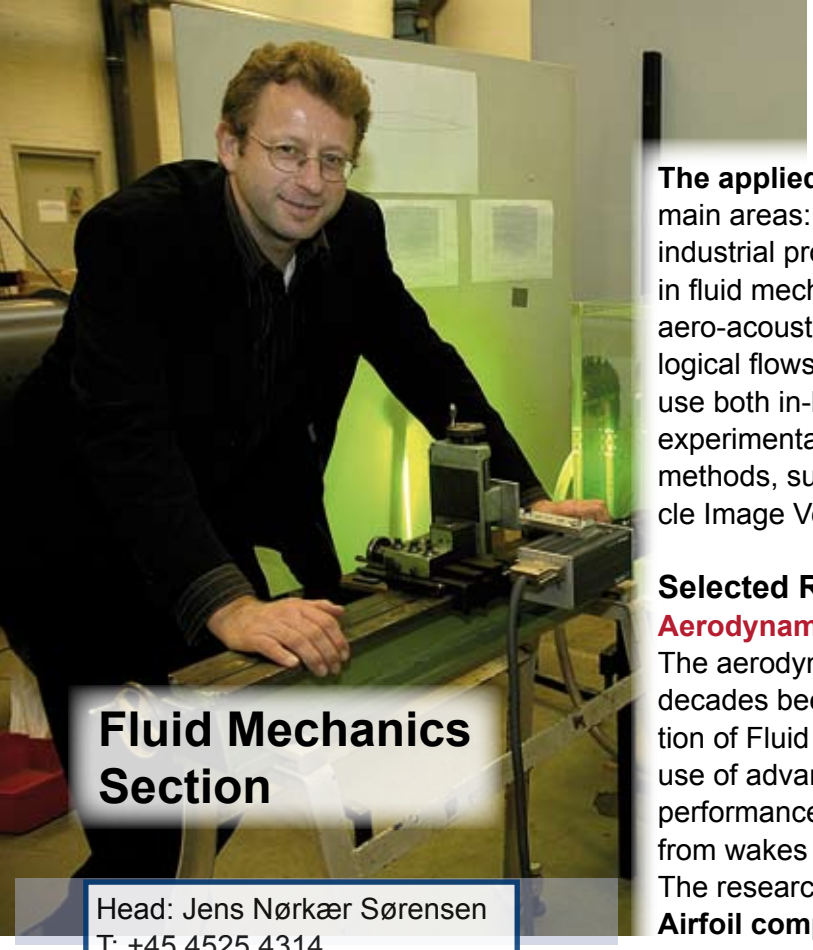
A significant amount of experimental work has shown that plastic deformation on a micron scale in crystalline solids is size dependent. Conventional crystal plasticity theories cannot account for such size effects.

A size dependent strain gradient crystal plasticity material model including higher-order stresses has been developed and implemented in a finite element program.

This model has been applied to the study of plastic flow localisation in single crystals, grain boundary effects in surface roughening, grain size effects in polycrystals and size effects in voided single crystals.



Polar shear stress contours around a microscopic void within a single crystal.



Fluid Mechanics Section

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The applied research topics of the Section focus on two main areas: aerodynamics of wind turbines and flow-related industrial process equipment. More fundamental research in fluid mechanics includes laminar-turbulent transition, aero-acoustics, rotating flows, room convection, and biological flows. In computational fluid mechanics (CFD) we use both in-house developed and commercial codes, and in experimental fluid mechanics (EFD) we use mostly optical methods, such as laser Doppler Anemometry (LDA), Particle Image Velocimetry (PIV) and related techniques.

Selected Research Topics

Aerodynamic modelling of wind turbines

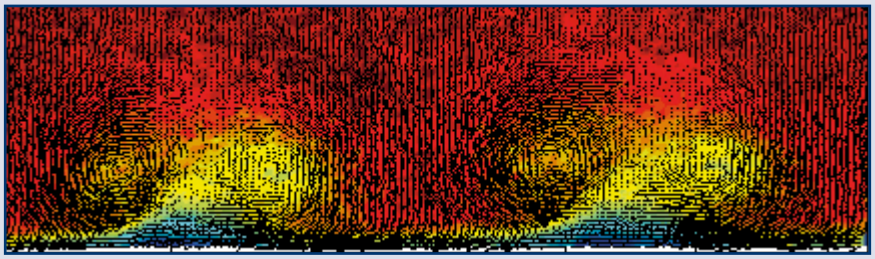
The aerodynamics of wind turbines has over more than two decades been one of the main research topics at the Section of Fluid Mechanics. Present efforts mostly concern the use of advanced CFD methods to simulate aerodynamic performance of complete rotor configurations and effects from wakes of wind turbines in clusters.
The research is divided into the following subject areas:
Airfoil computations are carried out to analyse basic aspects related to turbulence, laminar-turbulent transition, influence of roughness and dirt.
Rotor computations are performed for complete rotor configurations, including the boundary layer and the wake, using RANS and large eddy simulation techniques.
Wake computations using actuator disc/line modelling of the flow field in order to capture the main features of the overall flow without having to model the rotor in detail.
Wind farms
Today, wind turbines are often grouped in clusters, the so-called wind farms. To study the mutual influence of the wakes of the turbines grouped in wind farms Large Eddy Simulations are carried out using the actuator line methodology. [25], [48], [95], [177], [219], [235], [239], [248]

Analysis and Modelling of Vortex Generators

Vortex generators are used to control basic features of boundary layers in order to enhance the performance of e.g. blowers in ventilation systems, wind turbine blades, ship propellers and hydro-turbines. The flow around vortex generators is studied both numerically and experimentally.

Mixing of swirling flows in a bio-reactor

Experimental studies have been conducted in order to identify and investigate flows which potentially are more suited to culturing cells than those commonly found in bioreactors. Rotating cavity flows are considered in several configurations and various devices are tested to control the flow. A parametrical study has been carried out for different



configurations. The results are consistent with previous experimental visualisation and numerical work. [20], [79], [93], [96]

Turbulent mixing in industrial Flows

Numerical simulations of turbulent mixing usually have great uncertainties. New experimental methods offer detailed data, which can be used to evaluate turbulence models for mixing. In the project, typical industrial mixing flows are investigated both experimentally and by industrial standard numerical methods (Reynolds averaged simulations). [215]

The turbulent free jet

Describing and modelling turbulent flows are still a big challenge. The classical flow of a free jet is studied with new tools: Stereoscopic Particle Image Velocimetry (PIV) and Proper Orthogonal Decomposition (POD). This gives new insights into the dynamics of the free jet. [254]

SODAR measurements

A ground-based SODAR (Sonic Detection and Ranging) has been tested together with a traditional measurement set-up, consisting of cups and vanes for measuring wind conditions in terms of wind shear and wind direction at large heights. [168]

Nanofluidics

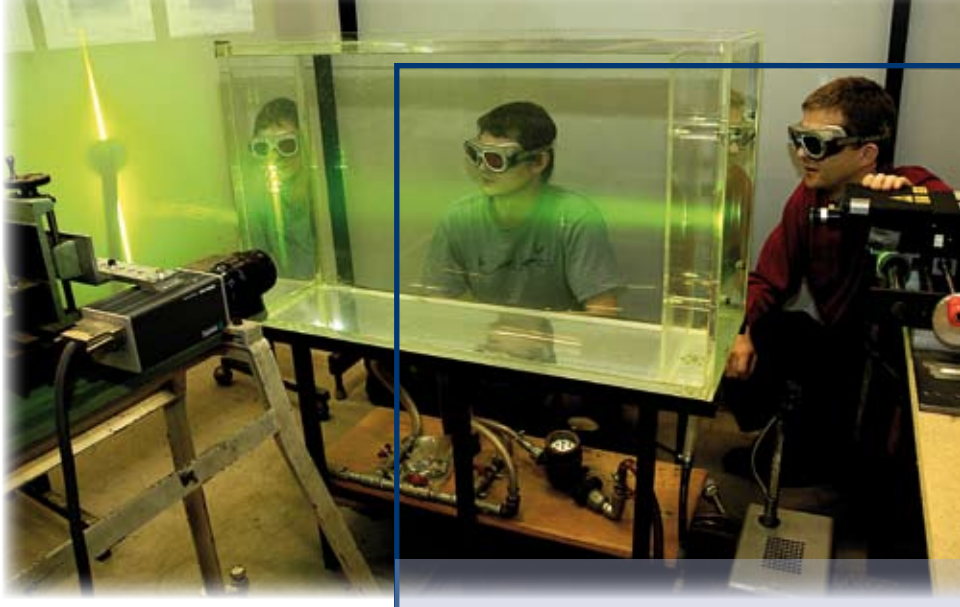
Various nanofluidic devices are simulated by use of atomistic descriptions. [92]

Particle-mesh simulations

Together with ETH a software framework for portable parallelisation of particle-mesh simulations has been established. [91], [119]

Biological flows

Models for fluid transport and ion fluxes in mammalian kidney proximal tubule are developed in collaboration with the August Krogh Institute, and feeding mechanisms of mussels are studied with the Marine Biological Research Center. [69], [71]



Jet flows are studied in various configurations using advanced optical measurement techniques.

Wind Tunnels are used to study the onset of turbulence utilising Laser Doppler Anemometry (LDA).

Coastal, Maritime and Structural Engineering Section

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The research topics of the Section include the design, analysis and operation of large maritime, coastal and land-based structures under natural loads, such as waves and wind.
The main research themes are:

- **Hydrodynamics:** Waves and currents and their interaction at restricted water depths, wave loads on ships, offshore and coastal structures, flows and loads on ship propellers.
- **Structures:** Design and analysis of structures; structural damping; composite structures; damage tolerance of sandwich structures.
- **Risk and reliability:** Risk acceptance criteria, risk evaluation, stochastic load and response modelling.
- **Sediment transport and morphology of rivers and coasts:** Waves and turbulence in surf zones, wave-driven currents and exchange processes, river bed forms, effect of structures on river morphology.
- **Interaction:** Performance of ships and large structures subject to wind and wave loads and their interaction with the environment.

Selected Research Topics

Risk analysis of navigational safety

Probability of collision and/or grounding, consequences of such events in the form of structural damage, extent of oil outflow and environmental consequences. Development of a numerical navigator for route evaluation.

Ship design

Photo: Anna Bruns

Ship design is a synthesis of applied engineering disciplines, such as hydrostatics, hydrodynamics, strength of structures and thermodynamics. At DTU naval architecture has been taught for more than 100 years, and the research and development work has always been aimed at developing methods and procedures which naval architects find useful in their daily work. Earlier, these activities were oriented towards empirical methods, but for many years the focus has been on rational methods based on first principles.

Ongoing projects include determination of sea loads, in particular extreme and critical loads and loads in the form of dynamical stability of ships.

Moreover, improved methods for calculation of second-order forces and moments, including drift forces and moments, are being considered.

To improve ship safety, collisions can be taken into account in a ship design, in the internal subdivision of the ship compartments and in the design of the bow structure.

Extreme value predictions and critical wave episodes for marine structures by the FORM

An effective stochastic procedure, based on the First Order Reliability Method (FORM), for extreme value predictions of wave-induced loads. Applications: A jack-up rig, parametric roll motions of ships, large motions of a TLP floating foundation for an offshore wind turbine. [61], [181], [182],[184], [214]

Run-up of long waves and tsunamis

The study is analytical and numerical. A first assessment of tsunami run-up and associated flow velocities at the shore-line. Wave generation due to landslides or tsunamis can be simulated. [75]

Generation of non-linear short-crested waves in deep water

Anomalies in published experimental data have been explained by the release of spurious free first harmonics, arising from the neglect of third-order components in the three-dimensional (physical) wave generation. A numerical investigation of the long-term evolution of doubly-periodic short-crested waves has been conducted. [38],[39],[76]

Third-order theory for multi-directional irregular waves

A theory for tri-chromatic water waves, providing the kernel of a third-order description of multi-directional irregular wave trains, allowing for an assessment of the non-linear interaction of three (or more) directional wave trains. [30],[74],[203]

Exploitation and protection of coastal zones

Coastal processes due to organised vortices, morphological modelling, stone protection, scour, liquefaction. [31],[33], [99],[100],[101],[102],[171]

Composite structures

Growth of debonds in foam cored sandwich structures exposed to cyclic loading. Buckling and propagation of debonds in sandwich columns. Compressive strength of FRP panels under the influence of imperfections. [202]

Structural dynamics

Dynamic response of structures, multi-body dynamics, damping of structures, time integration procedures. [57], [65],[88],[128],[175],[192],[193]

Danish Centre for Maritime Technology

In 2006 three projects started within the framework of the Danish Centre for Maritime Technology, which is a collaboration between Force Technology and MEK and partly supported by Den Danske Maritime Fond:

Ship propulsion in waves

Added resistance in irregular three-dimensional waves is considered. A non-linear and fully three-dimensional potential method is used. Calculations are performed in the time domain. Results will include motions as well as forces, including drift forces and moments.

Dynamic stability of ships

Excessive parametric roll of container ships in longitudinal waves is considered. A six-degree-of-freedom, coupled mathematical model is being developed, including non-linearities in hydrostatic restoring and hydrodynamic Froude-Krylov forces.

New engine concepts for ships

An evaluation of the technical, environmental and economic possibilities of alternative engines in large ships.

Photo: Carsten Lundager

Opening ceremoni in Folketinget. From left: Director Stig Sand, FORCE Technology, Head of Department Preben Terndrup Pedersen, MEK, and Minister for Economic and Business Affairs Bendt Bendtsen

Indoor Environment Section

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The interdisciplinary research programme of the Section aims at developing design criteria and innovative technical solutions for the creation of healthy, comfortable and productive indoor environments, which satisfy human requirements at low 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. The Indoor Environment Section constitutes the core of the International Centre for Indoor Environment and Energy, which was established in 1998 on the basis of a 10-year contract between the Danish Technical Research Council and DTU.

Selected Research Topics

Indoor environments and human comfort, health and productivity

Buildings which make their occupants feel unwell are unacceptable. Extensive field and laboratory studies are in progress to identify what makes buildings healthy.

New strategies for individual control of the environment

People are different and have individual preferences regarding the indoor environment. Strategies and technical systems are being developed to accommodate these differences through individual control of the microenvironment near a person.

Pollution sources in ventilation systems

We are rethinking how air should be handled in tomorrow's buildings. This includes the role of HVAC, heating, ventilating and air conditioning, components in air-handling systems, of ducts and of the air distribution system.

New methods for air cleaning

The use of a regenerative desiccant rotor may decrease the required outdoor air supply to a building. Extensive testing is in progress.

Allergies and indoor environments

Allergies are increasing worldwide. The causes are not known. Changes in the quality of the indoor environment are among the main suspected causes. With a focus on small children, the Centre is currently addressing these issues in extensive epidemiological studies of the home environment and its health effects.

Combined exposures to several indoor environmental parameters

Development of models for the prediction of human response to combined stress from e.g. noise, thermal environment and poor air quality.

Indoor environment in schools

At school children are often expected to learn under indoor environmental conditions which most adults would find unacceptable - crowded and noisy, with poor temperature control and poor air quality. A pilot project has shown that improving the indoor environment in a school would usually increase the ability of schoolchildren to perform schoolwork by up to 15%.

Chemical transformations

Chemical transformations may significantly alter indoor air quality. Chemical reactions occur both in the air and on indoor surfaces, including the surfaces of air filters in HVAC systems. The research activities include human exposure studies to assess the importance of various chemical reactions.

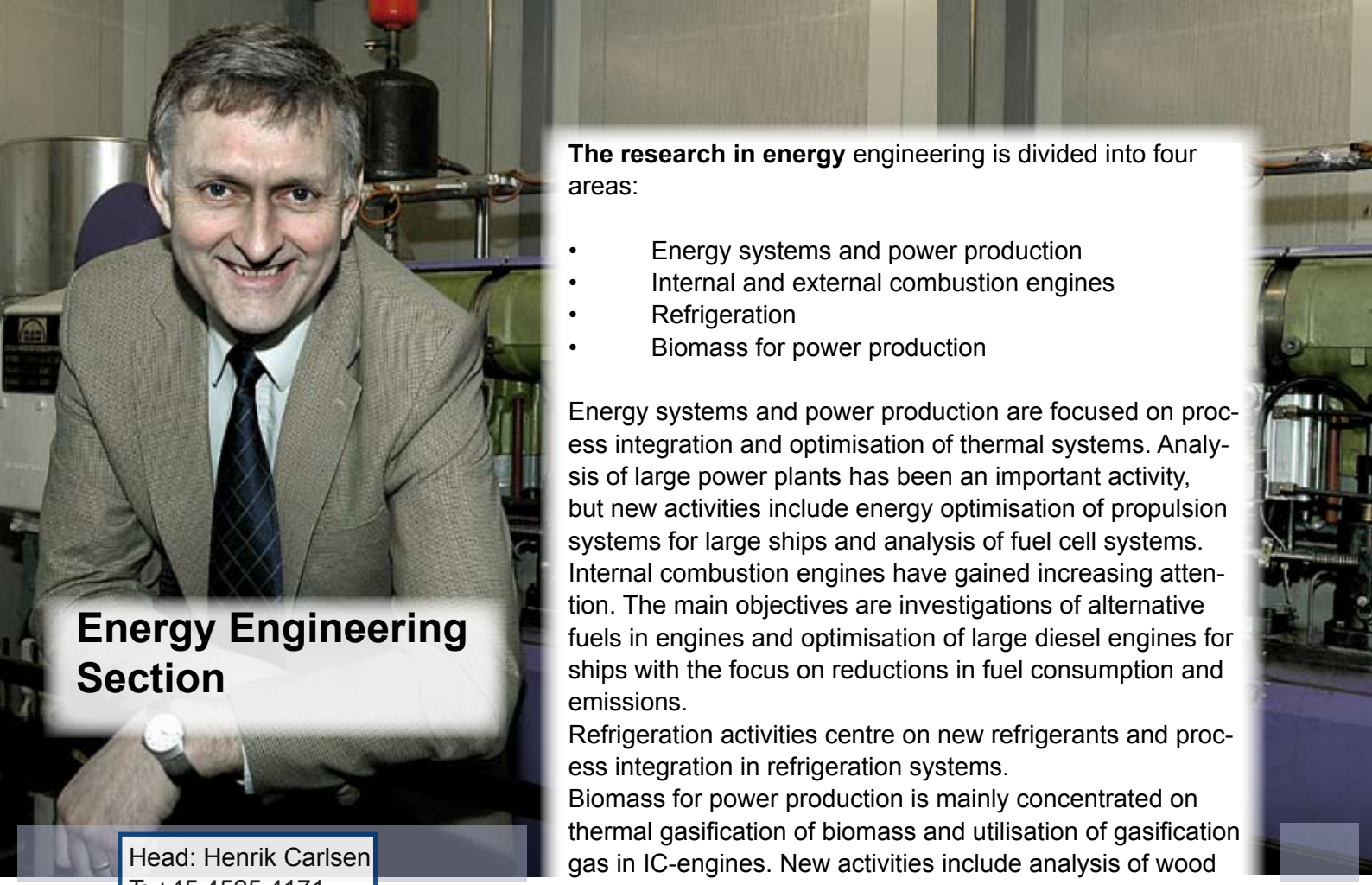
Aircraft cabin simulation studies

The effects of the environment in aircraft cabins on passengers are being studied in a simulated section of an aircraft.

Significance of sorption processes for indoor air quality

Sorption of chemicals on indoor surfaces may usefully supplement ventilation by reducing the peak load of pollutants in indoor air.

Student exercises in the Indoor Climate course



Energy Engineering Section

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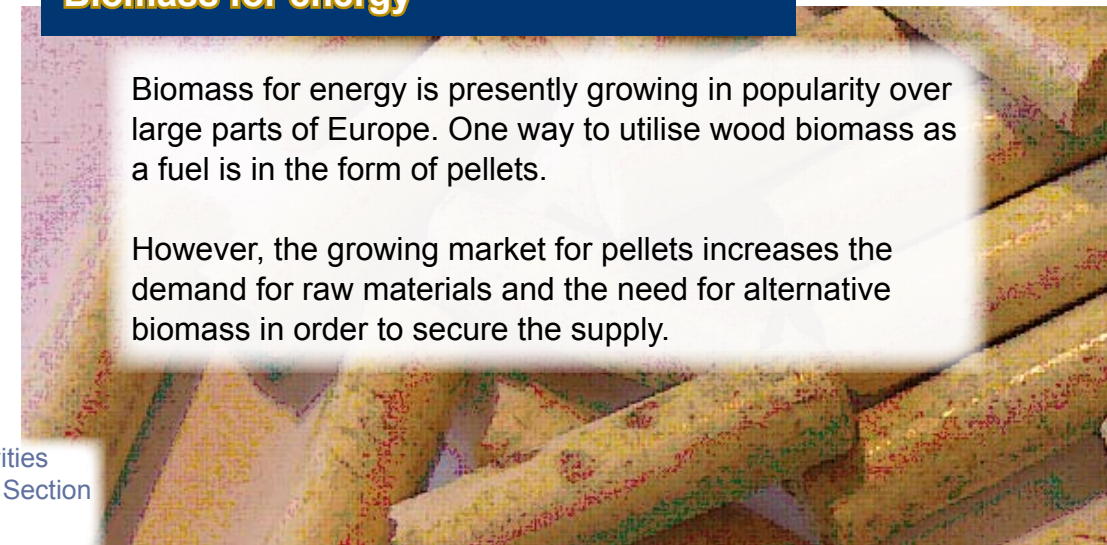
The research in energy engineering is divided into four areas:

- Energy systems and power production
- Internal and external combustion engines
- Refrigeration
- Biomass for power production

Energy systems and power production are focused on process integration and optimisation of thermal systems. Analysis of large power plants has been an important activity, but new activities include energy optimisation of propulsion systems for large ships and analysis of fuel cell systems.
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 the focus on reductions in 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. New 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 arean 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 the emphasis on process optimisation, energy efficiency, and automatic control.

Biomass for energy



Biomass for energy is presently growing in popularity over large parts of Europe. One way to utilise wood biomass as a fuel is in the form of pellets.

However, the growing market for pellets increases the demand for raw materials and the need for alternative biomass in order to secure the supply.

Selected Research Topics

Internal combustion engines and Ship propulsion

Project activities in the engine group include application of new fuels as dimethyl ether (DME) and gasification gas in spark ignition and diesel engines. Optimisation of large two-stroke diesel engines is a new area, which includes the influence of fuels and lubricants on emissions and wear. Investigation of alternatives to large two-stroke diesel engines for ship propulsion is part of new activities in the field of maritime technology.

Stirling engines

Stirling engines for small-scale CHP include optimisation of engine performance and application of renewable fuels such as wood chips and biogas.

Gasification and biofuels

A two-stage gasifier process is used for generation of virtually tar-free gas from wood chips.
Analysis and characterisation of wood pellets are important activities in the process of implementing biofuels in the energy production.

Refrigeration

Main activities include indirect cooling and substitution of CFC and HCFC refrigerants with natural refrigerants.

Power plants and boiler technology

Development of new or improved processes and process control for power plants by utilisation of computational tools.

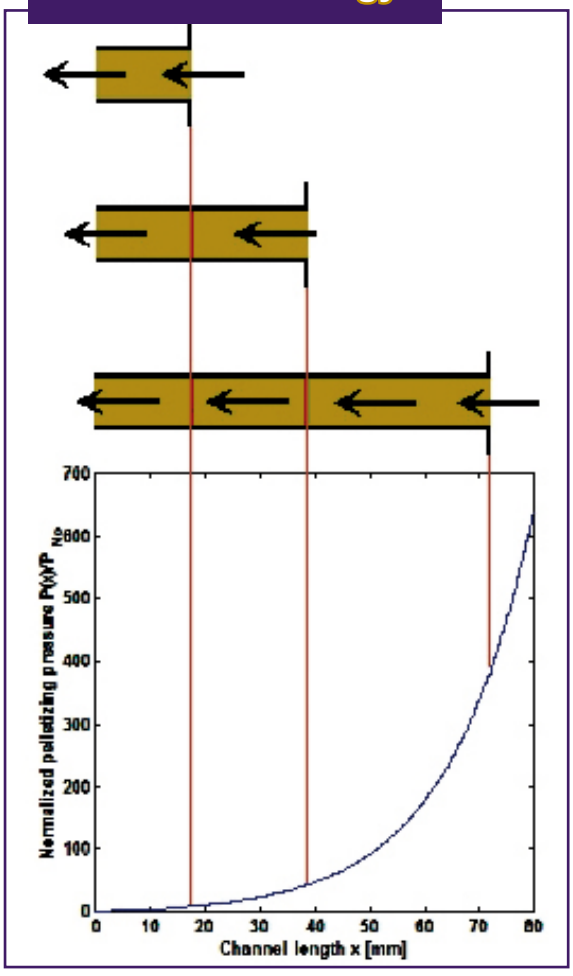
District heating

Optimisation of distribution systems for district heating.

Simulation and process integration

Many of the above-mentioned project activities involve development of mathematical models and methods of analysis for energy systems and components using numerical simulation.

Biomass for energy



At present, changes in the properties of the raw biomass often pose problems for the pellets producer, as the regulation towards a stable production is mainly on a trial and error basis.

The ongoing research project approaches the problem by combining structural studies with experimental investigations and modelling of the mechanical properties of the pellets during pelletisation.


AVAL ARCHITECT


GREAT
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NORTH

Education

Teaching Programme

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MEK Studies

MEK offers teaching programmes and courses at undergraduate, graduate and Ph.D. levels. The teaching programme is very comprehensive and covers coastal engineering, naval architecture, material and structural mechanics, indoor environment, energy systems, fluid mechanics, engineering design and product development.

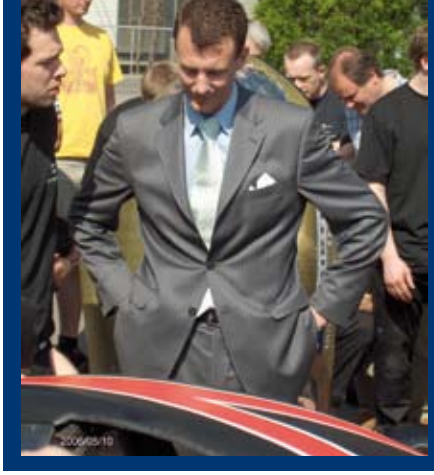
DTU fully complies with the Bologna Model, which allows students from EU member states to get mutual recognition of foreign qualifications.
Consequently, DTU offers three separate teaching programmes in engineering. The 3.5-year Bachelor of Engineering (B.Eng.) programme, the three-year Bachelor of Science (B.Sc.) programme and the two-year Master of Science (M.Sc.) programme. MEK is responsible for a considerable part of the curricula in mechanical and energy engineering as well as in design & innovation.

Upgrading Teaching Facilities

MEK now has for classrooms with a PC by each seat. This allows students to carry out simulations, analysis, CAD-modelling etc. as an integrated part of lectures. We expect that the demand for IT for students now matches the supply.
In 2006, classroom furniture was replaced and all classrooms are now equipped with comfortable and ergonomic chairs and tables. This ambitious undertaking was made possible by an extraordinary grant from the DTU central administration covering half of the expenses.
Further, a new laboratory for indoor environment tests and experiments has been established.

Teaching Methods

A broad range of teaching methods is employed at MEK, i.e. lessons, classroom teaching, course work, projects and laboratory experiments. The CDIO method – conceive, design, implement and operate – is being implemented in the B.Eng. programme.
A number of our courses utilise computer analysis, simulations and CAD/CAM-modelling. Using the latest computer-based tools is a high priority. For B.Eng. and B.Sc. students emphasis is placed on the use of commercial software, while M.Sc. students are trained in the use of advanced development tools.



ECO victory

MEK students drove 810 km on the equivalent of one litre of gas in the hydrogen car DTU-Dynamo and won the Urbanconcept class in Shell Eco-marathon 2006 setting an unofficial world record.

Design & Innovation Curriculum

The DTU departments IPL and MEK are responsible for most courses in this curriculum. In 2006 the number of applicants to the programme exceeded the number of places. This programme has attracted students to DTU who would otherwise have studied elsewhere.The full teaching programme for the Design & Innovation courses is now implemented.

International Masters Programmes

MEK has two international Masters programmes, “Wind Energy” and “Coastal and Maritime Engineering”. Both programmes have been very successful in attracting students, partly due to MEK’s internationally recognised research activities in these fields.

Teaching Efficiency – Teaching Quality

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. The number of students at the Department has increased over the last few years due to the new teaching programmes. However, despite the increase in student numbers per teaching staff member, staff efforts have resulted in further improvements in the quality of teaching.

During 2006 several of the B.Eng. programmes at DTU were accredited by the accrediting body of the Danish Ministry of Education. Among these were the B.Eng. in Mechanical and Industrial Engineering. The accreditation process revealed that the overall general quality of the educational programmes is fully satisfactory, but the communication on the DTU websites is to some extent esoteric. DTU will now focus on improving the communication.

First year hands-on engineering – take a lawnmover apart, put it back together and start it up

Sharing Knowledge with Future Generations

Every year a number of school and high-school students visit MEK. They take part in a variety of activities ranging from relatively simple workshops to advanced experimental work.

Our young visitors meet the real experts and use specialised equipment. Read more about two visiting groups.

Niels Houbak puts the bridges to the test

Building a Bridge: Schools at MEK

In December 2006, 45 secondary school pupils visited MEK as part of a five-day DTU Science Camp, which took the students to a number of Departments.

The MEK workshop was the very first stop of the camp, and Reader Niels Houbak, Section of Energy Engineering, started the day with a teambuilding exercise.
All students were very capable of tying their shoelaces. However, they faced a real challenge when they were asked to tie a bow in groups of two, using only one hand each.
”This exercise taught the students that you must communicate to solve the problem. Otherwise the right hand has no idea what the left hand is up to,” says Niels Houbak.
He wanted the children to learn about teamwork and communication, because these issues are at the very core of engineering work and would prove essential for the rest of the DTU visit.

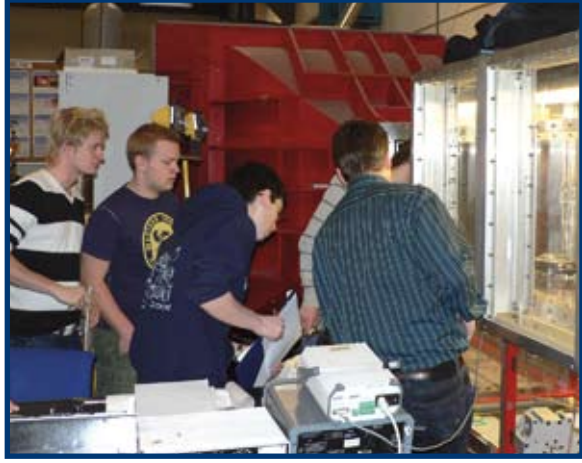
And the focus on communication helped the students during their second exercise at MEK: Constructing a bridge in groups of four.
The assignment was to build a bridge with a carrying capacity of 1 kg spanning 40 cm by use of long matches and sewing thread.
”I only gave the students a short introduction to the theory of bridge construction. Instead of following a set path, I wanted them to pick a solution and go through a process of trial and error. An engineer must be able to create something no-one has ever made before and will often have to go beyond theory. I wanted the students to try this process. ” says Niels Houbak.
At the end of the session, the students proudly presented their bridges and Niels Houbak tested the carrying capacity. Most bridges were able to pass the test.

High School: Lift and drag

Six high-school students decided to visit MEK, while working on the large Year 3 assignment for their final exam. Every year Associate Professor Robert Mikkelsen, Section for Fluid Mechanics, is joined by high-school students at a wind tunnel for a busy day of experiments. In 2006 the students had been asked to investigate the forces – lift and drag - on cars and airplane wings. They also had to look at the aerodynamics of these items.
"The schools have not got facilities for this type of experimental work. The students get to use very advanced equipment here at MEK and it makes the work more interesting. Also, they get a taster of life at the DTU campus," says Robert Mikkelsen. "I see this as a chance to share our specialised knowledge and interest youngsters in studying at DTU."

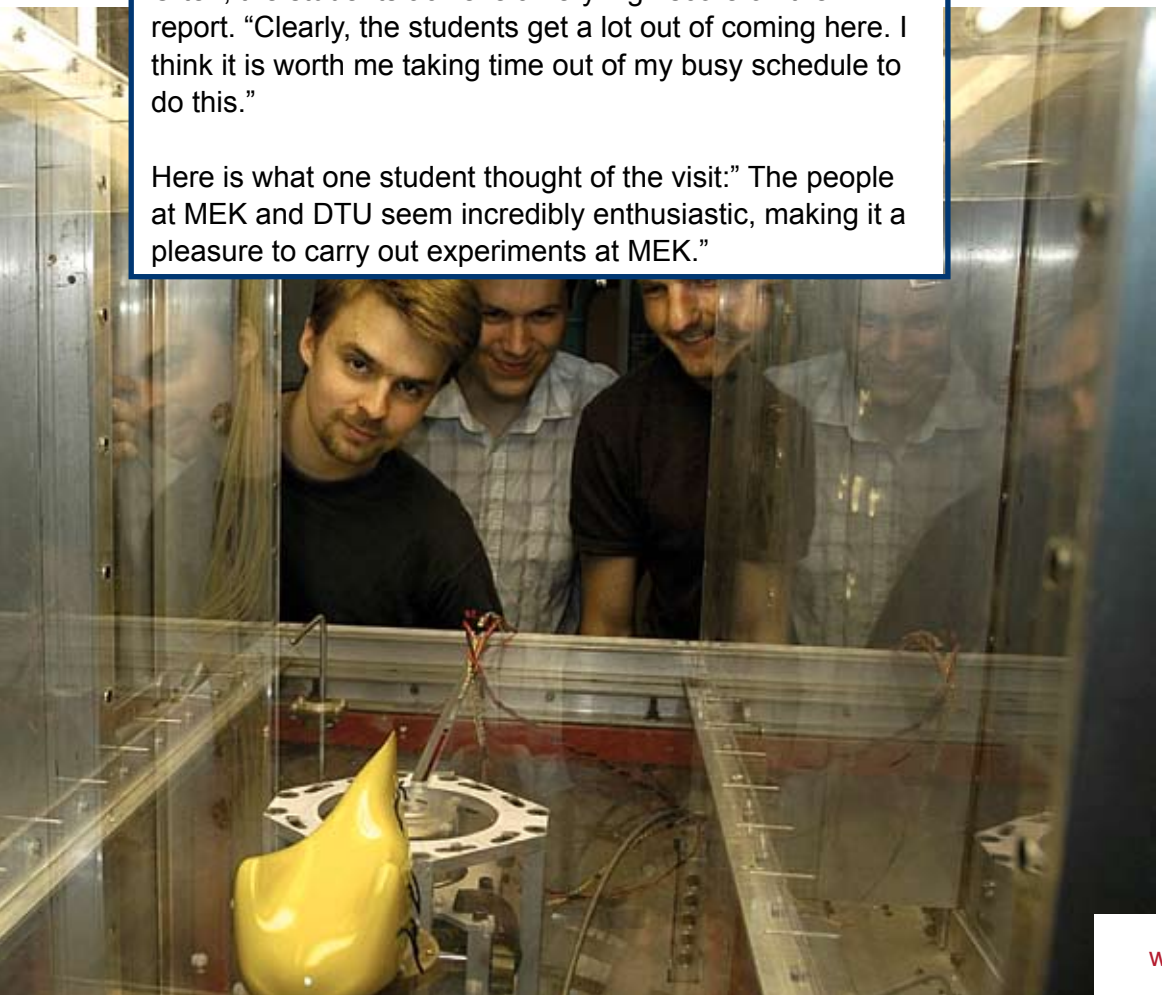
Either the students themselves or a teacher approaches Robert Mikkelsen, who arranges the workshop once or twice a year. "I make sure the students get through a series of experiments and have the measurements they need to write the report. Usually the students are very well prepared when they show up at MEK. I supply them with some notes in advance, but they have sought out literature and have a lot of questions for me."
Often, the students achieve a very high score on their report. "Clearly, the students get a lot out of coming here. I think it is worth me taking time out of my busy schedule to do this."

Here is what one student thought of the visit:" The people at MEK and DTU seem incredibly enthusiastic, making it a pleasure to carry out experiments at MEK."



Robert Mikkelsen demonstrates the wind tunnel

Explaining the aerodynamics of a wing



MEK students peering inside the windtunnel chamber

Awards & Staff

Head of Department, Professor Preben Terndrup Pedersen, was awarded the prestigious The Davidson Medal 2006 by SNAME, The Society of Naval Architects and Marine Engineers, at the Society's annual meeting in Florida, USA.

Professor Pedersen received the medal for outstanding scientific accomplishment in ship research.

Sune Pelle Borregaard and Martin Rasmussen: The M-prize (7,000 DKK), Mechanical Engineers Initiative Fund for Outstanding Final Projects, METAL 2006, Fredericia, Denmark, 2006.

P. Ole Fanger: University Professor at the Syracuse University in New York State, USA, 30 March 2006, for three years.

P. Ole Fanger: Honorary Member of Turkish Society of HVAC & R Engineers, TTMD, Istanbul, Turkey, 8 May 2006.

P. Ole Fanger: Honorary Professor, Huazhong Normal University, China, 2 October 2006.

P. Ole Fanger: Honorary Professor, Chongqing University, China, 10 October 2006.

P. Ole Fanger: Honorary Professor, Shanghai JiaoTong University, 13 October 2006.

Torben Ruby og Torben Jørgensen Herslund: Polymer-/Medicoprize (7,000 DKK), Mechanical Engineers Initiative Fund for Outstanding Final Projects, METAL 2006, Fredericia, Denmark, 2006.

Arsen K. Melikov: The Czech Air-conditioning and Ventilation Award 2006, Czech Society of Environmental Technology, Prague, 18 May 2006.

Arsen K. Melikov: The Distinguished Service Award, ASHRAE, Quebec City, 24 June 2006.

Kiril G. Naydenov: The Fanger Research Grant (25.000 DKK) from the Danish Engineering Society DANVAK, Copenhagen, Denmark, 5 April 2006.

Bjarne W. Olesen: The Exceptional Service Award, ASHRAE, Quebec City, 24 June 2006.

Kim Thomsen: Honourable scholarship (100,000 DKK), the OTICON Foundation, 2006.

Viggo Tvergaard: honoured by the arrangement of a 'Needleman-Tvergaard Symposium', held at Brown University, Providence, RI, USA, 16-18 August 2006.

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Publications

Publications

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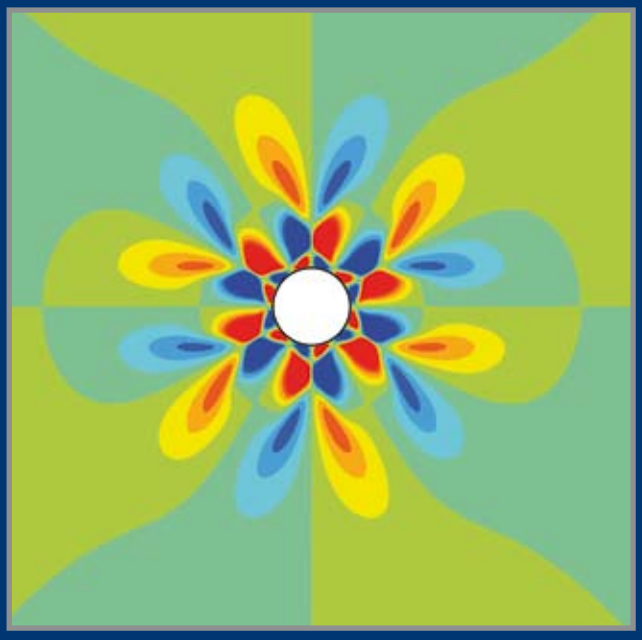

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