DTU's research environment: an innovative basis for patents and start-ups

By Lisbeth Lassen

At Section of Materials and Surface Engineering at DTU Mechanical Engineering, there appears to be a tradition for new patents and new companies. In 2010, the company Expanite was started on the basis of a new process for surface hardening of stainless steel. Again in 2014 the company TRD Surfaces was formed, offering a new surface treatment for hardening different types of metal. Both companies are built on patents and research. After another 4 years a new company is planned to see the light in 2018.

A creative space for researchers

Where do new business ideas and patent ideas come from? Do researchers begin the innovation process by studying applications in industry?

"It doesn't begin with industry, it begins with the major driver for science and innovation: curiosity," says Professor Marcel Somers, "We study materials and part of this is how they are or can be applied in applications and products. Often our curiosity is triggered by a material failing in a certain application, and we reflect on why it failed and what we need to understand in order to find an optimal match between material and application. Although this can be the impetus, at some point in time curiosity takes over and we focus entirely on the material without thinking about the eventual application. In this research stage, we come up with solutions that were never anticipated to exist. Once these are fine-tuned, and we have considered whether the ideas can be patented before we publish the scientific results, we revisit the application again. It is really cross-fertilization between scientific research and industrial applications." Senior Researcher Thomas L. Christiansen agrees: "It's not just driven by industry or the desire to fix a problem, it's the curiosity about what happens in the materials and how far you can push them that leads to knowledge-based materials solutions."

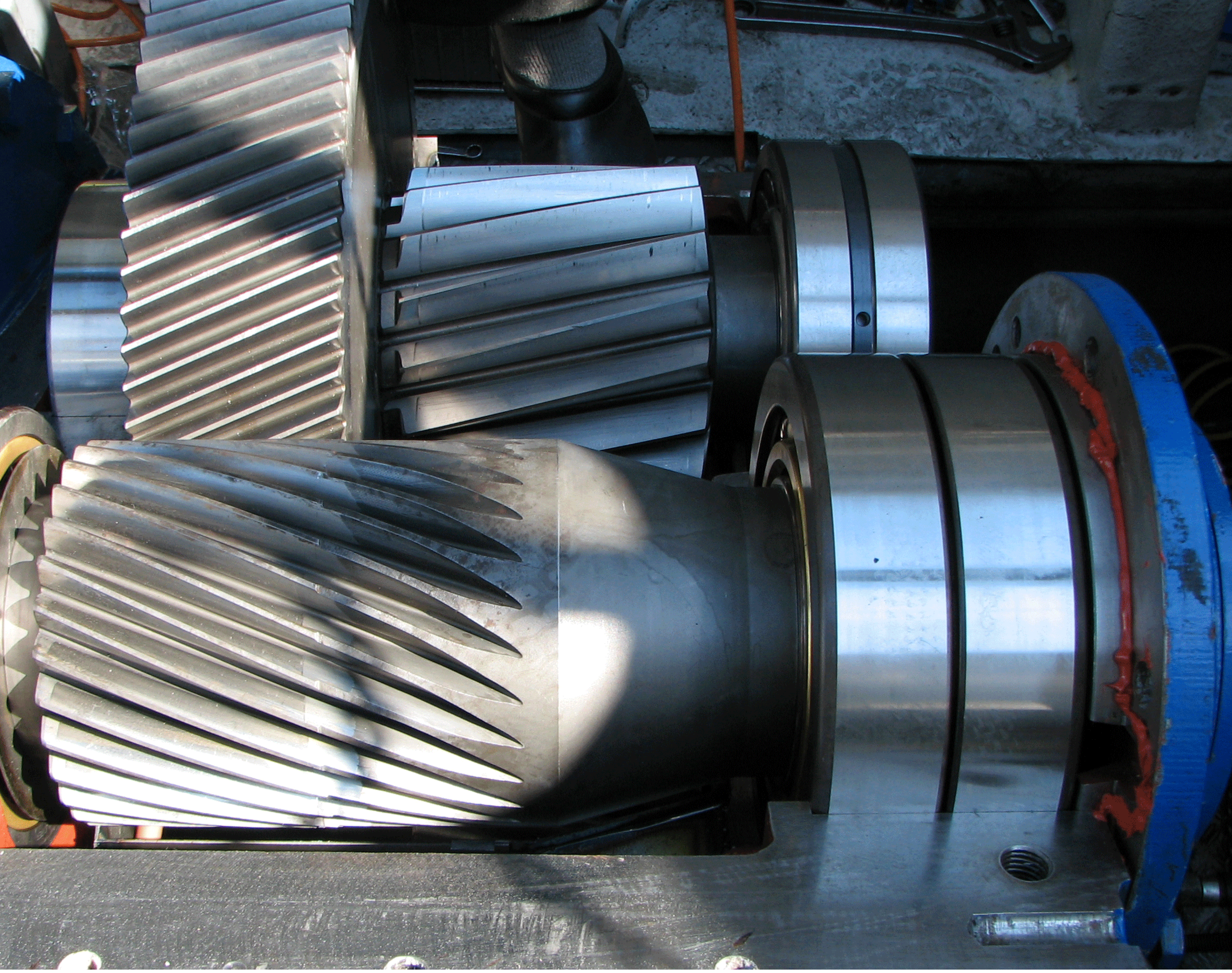
Both researchers describe the process of generating new ideas as a strong interaction between materials research, applications, laboratory investigations, industry collaboration, and back to research again.

"It doesn't begin with industry, it begins with the major driver for science and innovation: curiosity."

WhiteWind, a research project using knowhow from a spin out company

This cross-fertilization is very obvious in connection with the forthcoming WhiteWind project, a new Innovation Fund project lead by DTU Wind Energy and with substantial contributions from the Section of Materials and Surface Engineering and section of Solid Mechanics. The aim is to create a new solution that can prevent the so-called white etching cracks in the bearings of multi-megawatt wind turbines that lead to very expensive breakdowns of the entire wind turbine. As industry develops bigger and bigger wind turbines, the problem with white etching cracks has aggravated, a problem that so far has been impossible to predict.

"What happens is that these cracks appear in the bearings, maybe already after four months," tells Thomas Christiansen, "It causes a complete breakdown, and it is even more expensive to repair if the wind turbine is located in the North Sea. It can potentially be a showstopper for industry, and this type of failure is also known in other industries."

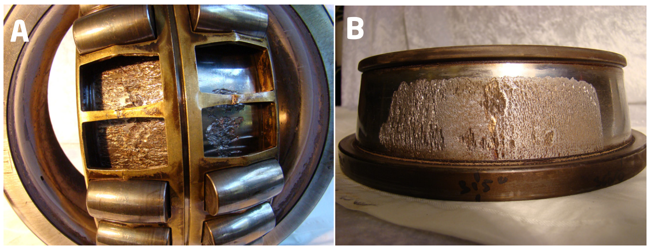


The photo shows the placement of the bearings and gears inside the nacelle of the wind turbine. Photo: Mogens Hvid

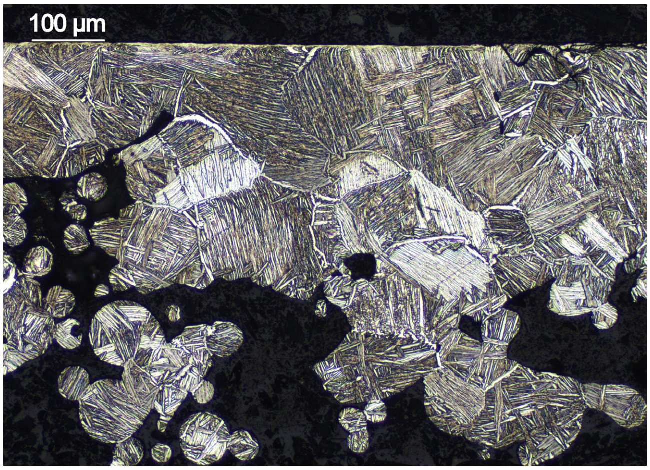
WhiteWind continues as part of the research in the strategic research centre REWIND that ended June 2017. "What we discovered and demonstrated in REWIND," says Marcel Somers, "was that when we introduced compressive residual stresses in the surface, we were actually able to avoid cracks as a consequence of rolling contact fatigue." An important focus of WhiteWind is understanding and optimizing the surface treatments to bring about controlled compressive residual stress distributions in the bearings.

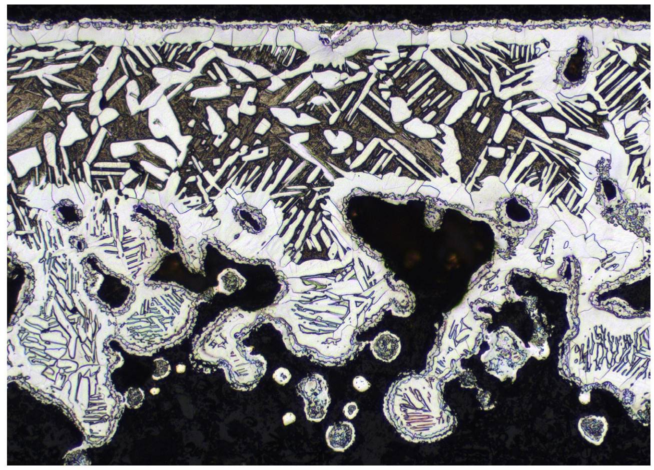
"We are using a different process now than in REWIND, because we are using stainless steel for the bearings," Thomas L. Christiansen tells. "In industry, a specific stainless steel quality called Cronidur does not show these failures when applied on a small scale. For this reason, they have an interest in a large scale version for wind turbines. Instead of a material that is difficult to apply to large scale, we have chosen stainless steel, a material we have investigated for several years. By developing a new surface treatment, we will design durable bearings."

The process will be carried out in collaboration with the partners Vestas and SKF. "This idea was born in our research environment several years ago, and our spin-out company Expanite will take it to the market. They are actually the project leader of WhiteWind," Marcel Somers relates. The problem with the bearings is not just happening in wind turbines. He recently visited a helicopter factory where they experience the same issues with the rotor: "The bearings showed the same problems with white etching cracks as the wind turbines, so this is really a generic problem. Finding a solution will eventually affect several industries," concludes Marcel Somers.



The photos show typical failure and damage of bearings which can be induced by so-called white etching. White etching cracks start below the surface and eventually leads to severe damage. The specific occurrence of the damage is difficult to predict, and the cracks may cause a complete breakdown of the wind turbine.





New methods for surface hardening titanium can solve the problem with wear resistance for the material and open up for a wide range of new applications. Left: A microscope image of a cross section of a pulley wheel before hardening. Right: The same cross section after the new hardening process, in this case the surface hardness has increased 5 times. Images from Emilie H. Valente's MSc project.

Understanding titanium: From patent to research project to a new company

The ideas in the new FTP project, MixTi, build upon a patent application that resulted from an earlier FTP project on metal release from implants, MeTimp, headed by Morten Stendahl Jellesen. Thomas Christiansen is project coordinator of MixTi, and he describes how that particular patent application gave rise to new questions:

"One of the materials of the previous project was titanium, and we were studying different kinds of surface treatments for it. We discovered that new methods for surface hardening the material could result in very high hardness and thick layers. These new solutions resulted in the patent application. Now, we want a better scientific understanding of how material is improved by the reaction with gases, so we are able to tailor the process parameters to obtain optimal materials performance. This has led to the formulation of the MixTi project."

Titanium is a high value material, not only because of its biocompatibility, but also because it is a lightweight material with excellent corrosion resistance, and it can be used in 3D-printing processes. The only disadvantage is the low degree of wear resistance and the high cost, facts that have limited the applications so far.

"Only imagination sets the limits for how we can use titanium, provided that we solve the problem with wear resistance. The MixTi project runs like a spine through a number of our research and innovation activities, and we hope to start a new company soon based on our research," Marcel Somers finishes.

A creative space for student start-ups

The use of existing patents is part of an extremely well-functioning process in the graduate course Innovation and product development where Associate Professor Thomas Howard has set up a creative entrepreneur environment as course responsible. This course has existed at DTU Mechanical Engineering for around 15 years in various forms, but only five years in its present and highly successful form, which is constantly creating many new companies. Each course concludes with "Spin Out Day", a presentation day where leaders from the business community are invited, and to whom the students present their new business ideas.

> **"Spin Out Day", a presentation day where leaders from the business community are invited, and to whom the students present their new business ideas.**

The business ideas are based on patents from DTU's "patent bank". The course usually has more than 100 participating students, and many teams go directly from the course into the innovative entrepreneur environment surrounding competitions such as Green Challenge, Venture Cup, and the Danish Tech Challenge. The winning team this year, Fishent, also participated in an innovation bootcamp as part of the prize.

Future innovation at the department

Researcher Matteo Calaon is innovation responsible at DTU Mechanical Engineering, a role supporting a wide variety of activities related to new inventions and patent applications. He also coordinates activities between researchers, students and the main administration at DTU.
"Future innovation activities will work towards consolidating and foster industrial collaboration at all levels improving technological commercialization of ongoing research projects with external entrepreneur to promote high-tech spin out companies," tells Matteo Calaon.

"We will stimulate early engagement of research by promoting networking activities with the aim to increase awareness of the ongoing research projects at DTU Mechanical Engineering. By doing this, the long-term goal is to stimulate the formation of cross-functional teams throughout the department operating as a network-like structure devoted to design and implementation of new internal projects. The network system will be optimized over time through the implementation of different pilot projects before becoming a powerful accelerating force towards incremental innovation."

The use of patents is an important part of the process of creating new spin outs in close collaborations with the industry, as the new innovation responsible tells:

"Timely implementation of patenting processes for the commercialization phase of future research works will potentially renew and improve problem solving in working practices. Innovation is also seen as the establishment of student projects in partnership with industry to promote commercialization of innovation as a means to meet society's goals for product/technology development."

Spin Out Day 2017 took place in the DTU Skylab. At the event, students from the BSc course Innovation and Product Development present their business ideas to the course responibles, Associate Professor Thomas Howard and Jakob Andersen, and leaders from the business community.

Facts about WhiteWind

WhiteWind: White Etching Crack bearing failures in wind turbines is a project funded with DKK 18,283,720 including overhead by the Innovation Fund. WhiteWind is a Grand Solutions project.

Hilmar Kjartansson Danielsen from DTU Wind Energy shares the project management of WhiteWind with Expanite A/S.

Researchers at DTU Mechanical Engineering
Senior Researcher Thomas Lundin Christiansen is work package leader for WP2: Surface Engineering.
Professor Christian Frithiof Niordson from Solid Mechanics is leader of WP4: Fracture Modelling.

Partners
Vestas Wind Systems A/S, Expanite A/S, SKF Gmbh, RWTH Aachen University, National Renewable Energy Laboratory

Fact about MixTi

MixTi, Mixed interstitial phases; a novel approach to tailoring the surface properties of titanium
The project is a FTP project funded with DKK 5.9 million including overhead, and Thomas Lundin Christiansen is project coordinator.

Researchers at DTU Mechanical Engineering
Senior Researcher Thomas Lundin Christiansen, Professor Marcel Somers, Associate Professor Grete Winther, Senior Researcher Kristian Vinter Dahl, Section of Materials and Surface Engineering.

Researchers from other DTU departments
Associate Professor Kenny Ståhl, DTU Chemistry.

Improved ways for designing big, complex structures

By Anne Kirsten Frederiksen and Lena Kristina Carlberg

A group of researchers from DTU Mechanical Engineering has recently obtained a new world record of giga scale resolution in the process of designing an aircraft wing. Now, the researchers want to go even further and develop a new paradigm for mechanical design of big, complex structures.

Giga scale resolution is a new world record

Professor Ole Sigmund and Associate Professor Niels Aage are the mainstay of the project NextTop that produced the giga scale resolution results.

They have worked with topology optimization for a long time. The technique is by now well-known and used all over the world in a variety of disciplines including mechanics and thermodynamics. Topology optimization is a mathematical method that optimizes material layout within a given design domain.

"Over the past years we have developed, as part of the project NextTop, a new model for calculating the optimal design of complex structures made by different kinds of materials. To demonstrate the model, we chose to design a wing structure for a Boeing 777, which contains more than 1 billion elements", says Professor Ole Sigmund.

Lower weight and environmental impact

The researchers were offered the opportunity to test their new calculation method on a European super computer through a grant provided by PRACE, Partnership for Advanced Computing in Europe. The resolution of the Danish researchers' new model is about 200 times higher than current state-of the art techniques – and the 8,000 involved computer cores needed several days to calculate a new design for the wing. When the calculations were finished, the result revealed a brand new design with unconventional curved details and a world record giga resolution.

"To demonstrate the model, we chose to design a wing structure for a Boeing 777, which contains more than 1 billion elements"

"Our approach is described in a paper recently published in Nature, one of the world's leading scientific journals. The method makes it possible to take a look at the design of the wing as a whole and at the same time see the smallest details of the many tiny elements of the wing. You can compare it with the experience of moving from the big and clumsy LEGO DUPLO bricks to the finer and more intricate detailed standard LEGO bricks. This made a world of difference regarding accuracy and the possibility of working at different scales," says Niels Aage.

The method revealed an optimized design of an aircraft wing with curved ribs instead of the straight ribs known from present wings. At the same time, the model found an advantage in adding fine supporting struts. The new design led to a wing of less weight and consequently a reduction of fuel consumption and carbon emissions during flights.

Screen shot from the TopOpt 3d App downloadable from the App Store.

Next step is a new design process

The two researchers are of course proud of their new world class resolution, but they are already in charge of a new project, InnoTop, which they hope will make it possible to go even further.

"Our vision is to develop a new paradigm for design processes. We want the giga resolution to work real time. This will make it possible for experts from different areas to be part of the same process and profit from the possibility of changing the design regarding the consequences of different expert inputs. It will make the design process more efficient and avoid decisions that have to be changed later, when new experts get involved and add new requirements," explains Ole Sigmund.

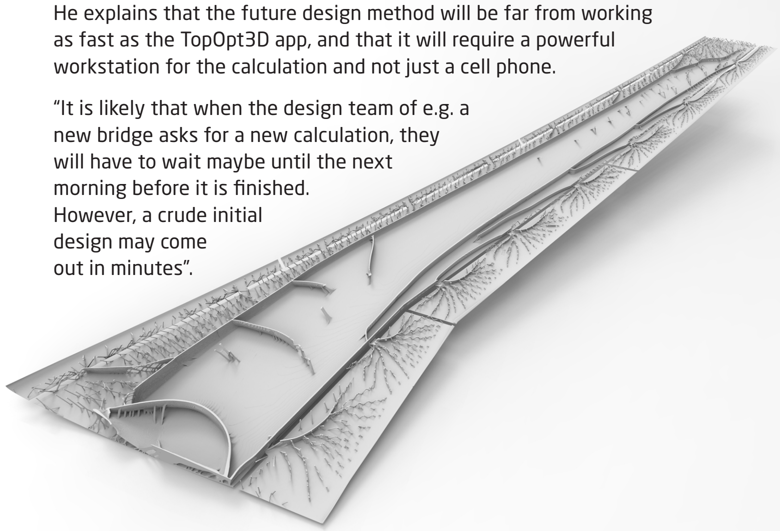
Combination of two existing techniques

The very ambitious project will be based on the combination of two different techniques, which are both developed by the researchers themselves or colleagues at DTU. It is the TopOpt3D app and the first model for topology-optimization developed 30 years ago.

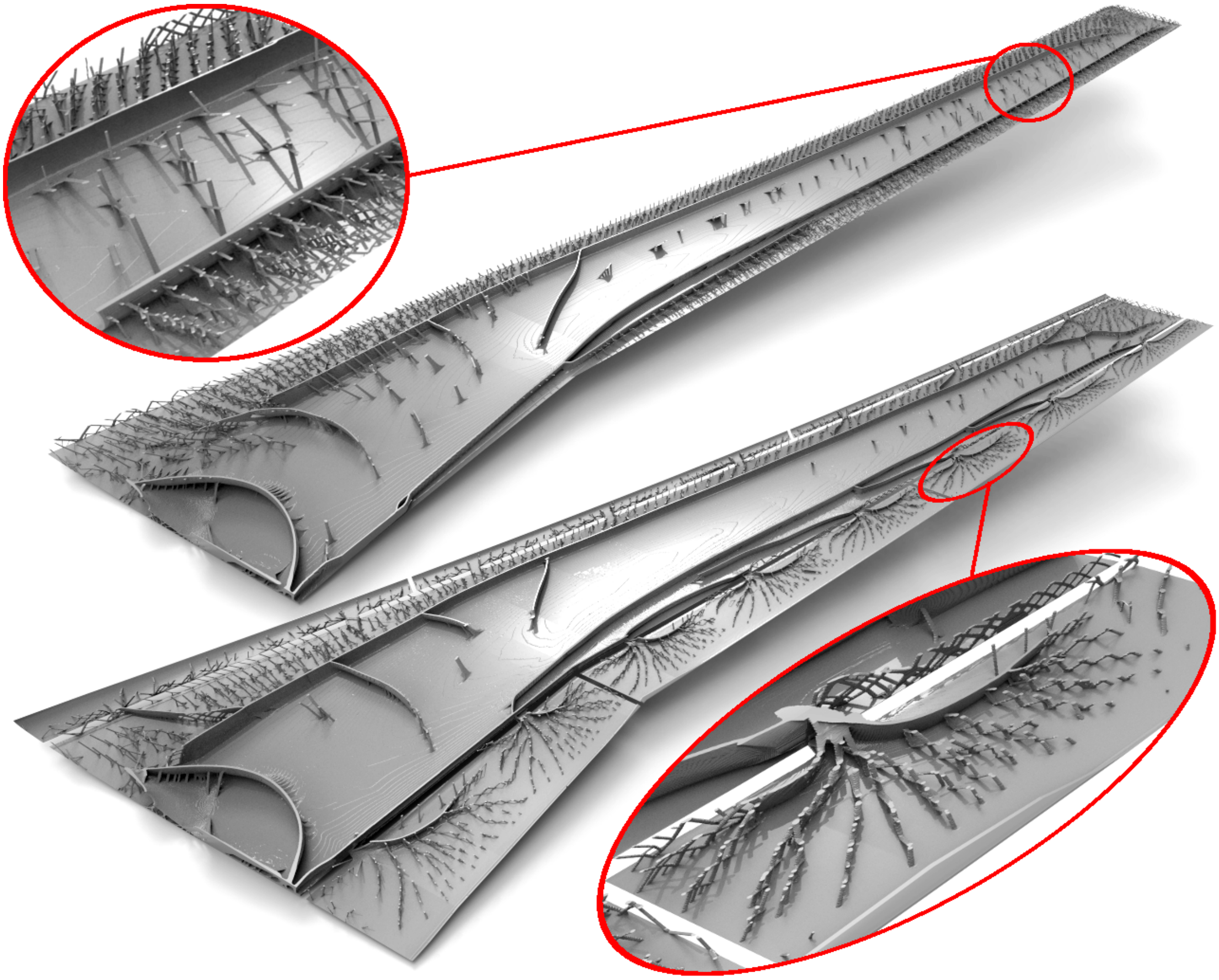
"Ole and I are part of the team that developed the TopOpt3D app. The app is an interactive topology optimization tool in 3D. The app allows the user to change loads, supports and the volume fraction interactively and watch the design evolve to a new optimum in real time. At the moment, the app can only illustrate rather simple structures and changes, but we want to develop it to handle bigger and more complex structures," says Niels Aage.

He explains that the future design method will be far from working as fast as the TopOpt3D app, and that it will require a powerful workstation for the calculation and not just a cell phone.

"It is likely that when the design team of e.g. a new bridge asks for a new calculation, they will have to wait maybe until the next morning before it is finished. However, a crude initial design may come out in minutes".



Aerial view of the optimized load carrying structure of a Boing 777 wing.



Different views of the optimized B777 wing structure obtained with a giga resolution topology optimization frame work developed at DTU Mechanical Engineering.

See changes real time without a super computer

The focus of the new InnoTop project is to find out how to make a new design process that can be handled without a super computer, which was necessary in order to obtain the first giga resolution result. The goal is therefore to find methods that reduce the amount of calculation times by 4-5 orders of magnitude in order for regular computers to handle it.

The reduction of calculations will partly be obtained by revitalizing the first topology optimization method developed by Bendsøe from DTU and Kikuchi from the University of Michigan back in 1988. The original method was since then abandoned, but offers a multiscale approach, which Ole Sigmund and Niels Aage find promising.

Revitalization of an old method for topology optimization

The original method contains multiscale information about density distribution. The way of working with information in the 30-year-old method has so far inspired to reduce computing times by almost two orders of magnitude in 2D and more is expected in 3D.

"We are collaborating with international and local colleagues to transform the multiscale information of the old method into 3D structures by computer graphics methodologies, which can be used in CAD systems. CAD systems will make it possible to implement our new

"My vision is to be able to give industry the tools for a new process before the InnoTop project ends in six years,"

method in companies and organizations that already use CAD for design processes. Our aim is that the new method will be able to deliver a quality just as good as the giga resolution we obtained with the super computer when we developed the new Boing 777 wing design", says Ole Sigmund.

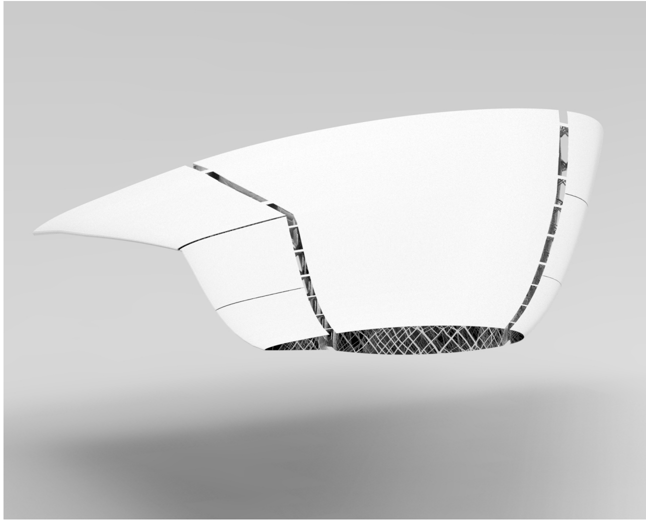
New kind of design process

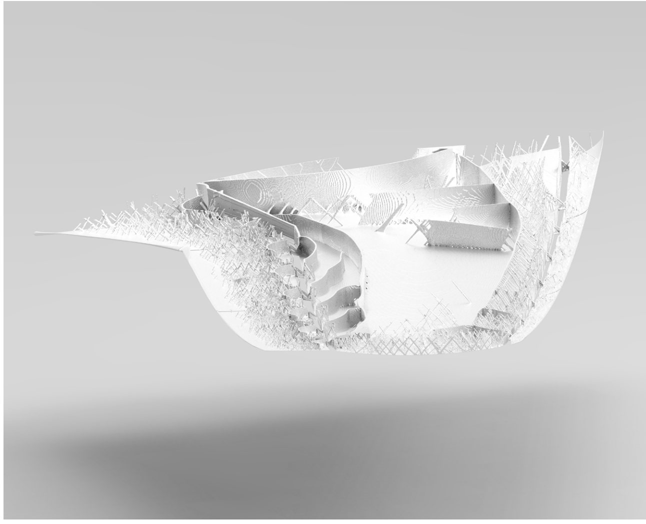
When all information on multiscale and microscale structures is gathered in a CAD system for example, it will be possible to show the design evolve in real time. Different technical experts can work together and simultaneously give their inputs and restrictions to the design of an aircraft wing for example, no matter whether it concerns energy optimization, passenger experience, weight, material composition or another parameter. It will all be mixed in the new method and give the involved experts the possibility to see how the design evolves when they change one of the parameters. Exactly as you are able to see the design change in real time in the TopOpt apps today.

"In that way, we are able to create a much more efficient design process, which will be a game changer. Many different industries will benefit from a new process – not only when designing complicated structures as bridges or aircrafts, but also when designing new materials, new products, buildings, etc. My vision is to be able to give the industry the tools for a new process before the InnoTop project ends in six years," says Ole Sigmund.

The researchers do not only want to make a new design paradigm possible. They also want to extend the possibilities for design with their new model.

"It is interesting to be able to design an optimal construction of a new wing of an aircraft. But we want our new design method to go further and be able also to calculate the best shape of a wing in proportion to its purpose. No one says that an aeroplane needs two traditional wings and a tail plane; the model can probably design a much better layout of a plane for transportation of people and goods," says Niels Aage.





B777 wing structure viewed from the tip. Left: with upper skin layer and right: with upper skin removed.

Facts about NextTop

The NextTop project: Topology Optimization - the Next Generation, ran from 2011-2016 and was funded by VILLUM FONDEN with DKK 12.1 million. Professor Ole Sigmund coordinated the project.

Project outcome
Amongst others, topology optimizations methods that focus on novel possibilities and constraints associated with additive manufacturing methods.

Paper in Nature
Aage, Niels; Andreassen, Erik; Lazarov, Boyan Stefanov; Sigmund, Ole. Giga-voxel computational morphogenesis for structural design. In: Nature, Vol. 550, No. 7674, 2017, p. 84-86.

See the TopOpt groups webpage: www.topopt.dtu.dk for more information.

VILLUM FONDEN

Facts about the Villum Investigator project InnoTop

The InnoTop project: Interactive, Non-Linear, High-Resolution Topology Optimization is funded by VILLUM FONDEN through a VILLUM Investigator Project awarded to Ole Sigmund. VILLUM FONDEN (a part of THE VELUX FOUNDATIONS) is a non-profit, private charitable foundation that supports technical and scientific research as well as environmental, social and cultural projects in Denmark and internationally. The 6 year project was initiated on September 1st, 2017. The total budget is 36.2 million; 31.1 million is funded by VILLUM FONDEN.

Researchers at DTU Mechanical Engineering and DTU Compute
From Mechanical Engineering: Villum Investigator and Professor Ole Sigmund, Associate Professor Niels Aage, Associate Professor Casper Schousboe Andreasen, Senior Researcher Fengwen Wang and from DTU Compute: Associate Professor Andreas Bærentzen.

VILLUM FONDEN

Do it and learn - Educating engineers at DTU Mechanical Engineering

By Lisbeth Lassen

Education is a highly prioritised area at the department, and during last year, several initiatives have been taken to develop the competences of the lecturers at DTU Mechanical Engineering.

Associate Professor Claus Thorp Hansen is pedagogical coordinator, and he coordinates activities between the department and LearningLab DTU, a centre offering pedagogical training at the university. He has been pedagogical coordinator since 2012, and in cooperation with LearningLab DTU he has developed and is co-responsible for the UP education (University Pedagogy for Experienced Teachers).

"This summer we held a department seminar in order to educate more pedagogical supervisors at the department," Claus Thorp Hansen tells. A pedagogical supervisor is assigned to every new teacher when they enroll in UDTU (Education in University Teaching at DTU) in order to qualify their teaching. "At our seminar, we spent half a day discussing what kinds of profiles we would like the graduates from the different Master's programmes to have. And for the first time, all sections but one has a pedagogical supervisor, so now it's possible for a new teacher at any section to have a supervisor with a different scientific focus. This way we avoid the temptation of discussing our research, and not our teaching."

Claus Thorp Hansen describes good teaching today: "For teaching to be excellent, it is fundamental to be aware that the more we lecture as teachers, the less active the students are. Learning happens when you are working actively with a subject, and if the students just sit in an auditorium and passively listen and maybe even lose concentration, they will not achieve much. The essence of excellent teaching is to create learning situations where the students are working actively with the subject, and where the purpose and application is clear."

"For teaching to be excellent, it is fundamental to be aware that the more we lecture as teachers, the less active the students are.

Updating and qualifying our skills and competences in teaching is important, as students today often have very different learning preferences or strategies than we, their lecturers, had when we were students years ago. So pedagogical strategies need to change and expand focus, and this is part of the course content in the UDTU and UP programmes.

The power of a relevant case

Activating the students is already part of the teaching in many courses at DTU. Professor Tim McAloone, Lecturer of the Year 2017, uses cases and examples of problems as an integrated part of his teaching. He is course responsible for the Master's course "Development and operation of product/service-systems" and the Bachelor courses "Product life and environmental issues" and "Sustainability in engineering solutions".

"I use examples the students can relate to, simply to start them thinking," Tim McAloone says. "I have many years of experience with using cases, which also includes some bad experiences of using case examples that are too complex for the students to understand - and this is not the way to do it. One needs to find examples where the

Students from Professor Tim McAloone's courses often take their business ideas to innovation competitions. Here Natasha Fiig and Kathrine Hagen have just won the 1st prize in the Green Challenge in the category Bachelor final project for their project "Roof Tiles from Thin Plastic Waste in India". MP Mogens Lykketoft is presenting the award of DKK 30,000. Photo: Mikal Schlosser

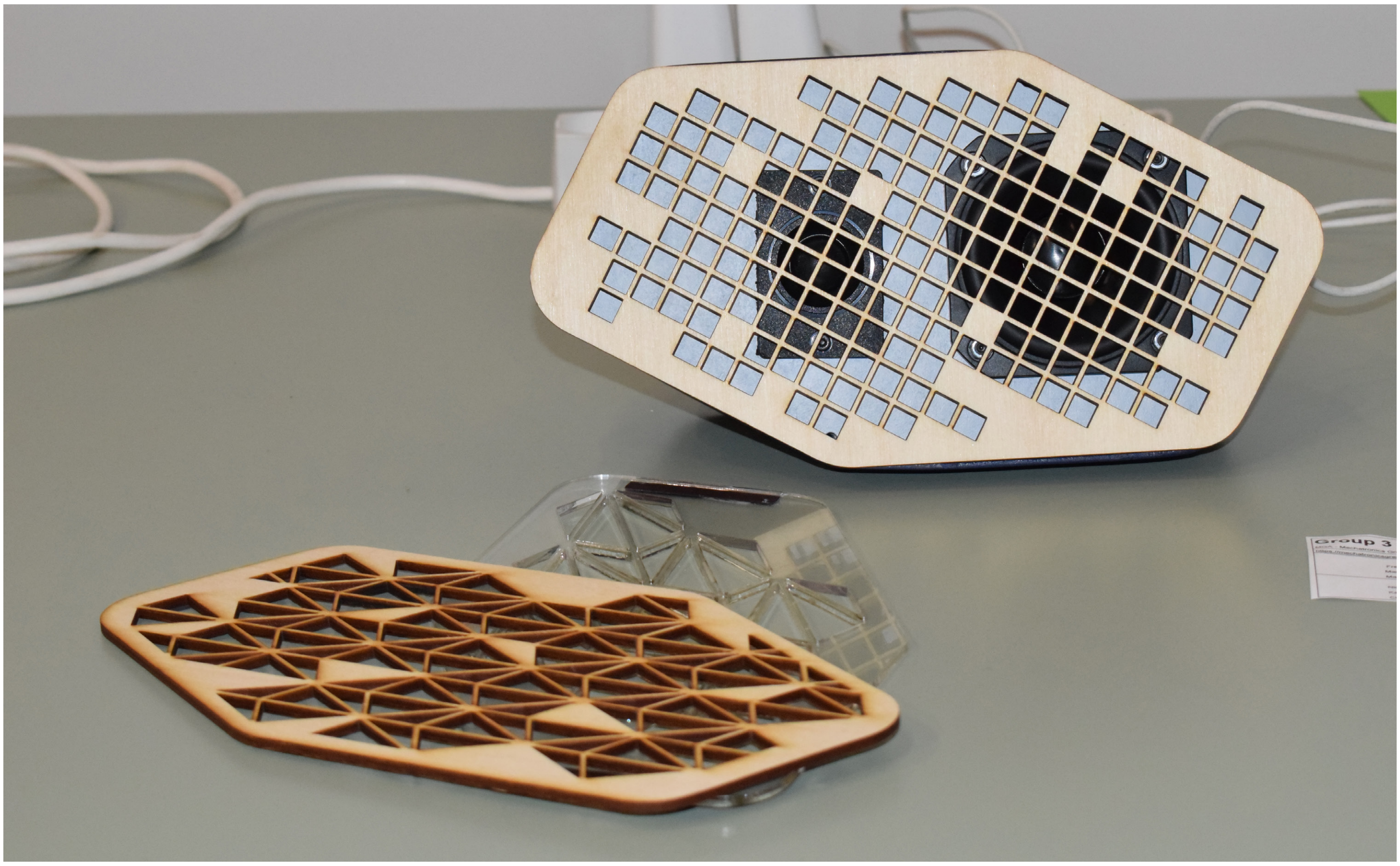
students can focus on exactly the point or the issue that one wants them to understand, and for this reason I often begin by bringing many everyday products as examples, like tuna cans, milk cartons, children's shoes or bicycle lights."

The students are then asked to consider design and environmental issues related to the different products that I present to them. Slowly but surely – as the students' understanding at the theory develops, the case examples get more complex too.

"All our courses are about designing better and more environmentally considerate products and systems, while also considering economical and business aspects," he continues. "In the design phase, engineers should consider all life phases of a product: Raw materials, production, transport, use and finally end-of-use. We train the students to think of all the possibilities and necessary considerations in every single life cycle phase. The basic idea is to make them think holistically and methodically at first, and then we can raise the level of difficulty when they grasp the basics."

In the Master's course "Development and operation of product/service-systems", Tim McAloone frequently spends the first day on letting his students produce orange juice by different means. In the experiment, the students are required to make juice using an electrical juicer or a hand-powered juicer, after being asked to consider which method is the most environmentally sound. "They all start by saying that the hand-powered juicers are the most environmentally beneficial. Then I give them 4 oranges each and 1 minute to produce as much juice as possible. The electrical juicer always produces the largest amount of juice. Afterwards, we discuss the exercise and reach the conclusion that a small portion of electricity for an electric juicer might just be worth saving the last drops of juice from an orange that has travelled thousands of kilometres in a truck to reach Denmark! This leads us to assessing the total costs and environmental loads of producing the juice, including the transport of oranges from Spain to Denmark. We can calculate how many megajoules the transportation takes, compared to the few megajoules it takes to produce considerably more juice by using the electrical juicer."

Is juice produced with a hand-powered juicer more environmental friendly than juice produced with an electrical juicer? The juice experiment is part of Tim McAloone's course "Development and operation of product/service-systems". Photo: Colourbox



A wireless, 3D printed loudspeaker made by a student team at the BSc course "Mechatronics Engineering Design". Bang & Olufsen supplied the hardware for the prototypes.

This hands-on case of different means of producing orange juice accelerates the students' understanding and analytical approach to subjects like life cycle thinking, product development, and sustainable innovation.

Professor Tim McAloone's use of cases and hands-on examples was highlighted as one of his key characteristics as a teacher by a number of students who nominated him for the award Lecturer of the Year 2017.

Mechatronics: from a conceptual course to hands-on prototyping

A number of courses at DTU Mechanical Engineering have undergone a transformation from lecturing to activating the students with hands on projects, among them the BSc course "Mechatronics Engineering Design". Associate Professor Ali Gürcan Özkil is course responsible and he describes this transformation: "The course was created because we needed the skills within the field of mechatronics in the curriculum, and we had to have a course that incorporates skills from a broad spectrum like electronics, software engineering, mechanics, design, and entrepreneurship. In the beginning, it was very conceptual and similar to other courses with classroom teaching and slides, but it soon evolved into being extremely hands-on and focused on prototypes."

The main focus of the course is still the same theory, but with assignments and the so called sprints which are short time projects for teams. The course is organized with four sprints during the whole course, so the structure is 4-5 weeks, and then one project, 4-5 weeks, then another project. The first project is more thematic and the last is combining the different subjects. All teams end up with a functioning prototype.

Ali Gürcan Özkil definitely sees great advantages in learning with hands-on design projects and prototyping for future engineers: "It's what we are looking for in the modern world: If you talk to people who hire students when they graduate, when you read academic papers, when you hear politicians talk, the theme is all about this. People who can actually do things; engineers who can engineer."

"We can see that prototyping is extremely important if you want to make a start-up, or if you want to work for a large company developing new products."

According to the course leader, the ability to conceive and create prototypes is of great importance to engineers, and especially to design engineers or engineers who are going to contribute to industry. "We can see that prototyping is extremely important if you want to make a start-up, or if you want to work for a large company developing new products. Prototypes are where ideas make or break. If you can't prototype a nice design from the screen or from some calculations, it doesn't become anything. We are still living in the physical world, and that's why prototyping is so important in all engineering education, and especially in design engineering and mechanical engineering."

Basically the students learn to cross the gap from calculating something and drawing it on a screen, to creating a proof of concept that actually works according to the laws of physics and the limitations of manufacturing. Mechatronics is also a subject that forces each student into developing knowledge about a wide variety of disciplines from electronics, sensors, software, mechanics, design, and manufacturing. The students in the course come from different study lines, most of them are from Design and Innovation, but there are normally also students from Mechanical Engineering, Software Technology and even external students.

Engineers with Swiss-army knife profiles

The students are developing cross disciplinary skills when working with prototypes, and this has an important perspective for industry and society. This became very apparent to Ali Gürcan Özkil at the seminar "Mechatronics in engineering education", which was held this summer:

"We hosted a seminar in mechatronics in June, and the feedback we received from the industrial participants was that what we need are engineers who can pick up the problems and come with solutions right after their graduation. This is especially important in Denmark where the economy is driven by small to medium sized companies that don't have the strength and the power of very large companies. For small companies, it is a luxury to just have one engineer who does one single job; they need people who are like Swiss army knives and who can at least learn what to do when facing problems. The problems they experience can't be put in boxes as just a mechanical problem, a software problem or an electrical problem, often it's a combination of these things in real life," he says.

The cross disciplinary approach that the students learn by working hands-on with prototypes is a very relevant approach in relation to digitalization and the development of smart or intelligent products.

"So our course gives the students a real perspective on what is happening in industry and in society. Some of my former students are now hired in companies, where they face the same problems. Hearing aids, for example, are not a mechanical or an electronical product anymore, and they connect to the internet and communicate with other devices. Even conservative companies are considering how they can make their products smarter. We need to act on this development," concludes Ali Gürcan Özkil.

Presentation of the new prototypes, 3D printed wireless speakers, manufactured by the students in the BSc course "Mechatronics Engineering Design", where Associate Professor Ali Gürcan Özkil is course responsible.

See examples of prototypes from the course Mechatronics Engineering Design: