What happened at the Lustrum Day?
Index

Foreword 3
Prof.dr.ir Marc Geers reflects on his tenure as EM’s Scientific Director 4
Koiter lecture: 6
The implications of highly stretchy, highly tough hydrogels 6
Giant Footprint 9
The EM Marketplace: Trading innovation 10
Brilliant minds 12
Sharing impressions 15
Alumni lectures 16
Good vibrations: A new theory on what makes structure shake 18
What are the most exciting future applications of nonlinear mechanics? 20
The history of Engineering Mechanics 22

ABOUT LIVE MAGAZINES
Events are volatile, a Live Magazine remains. Live Magazines captures the knowledge, energy and inspiration of events in a keen, vivid publication made on the fly. This increases and extends the impact of an event and increases engagement with participants and (future) partners.

We are making a report today that will help you get started tomorrow.

This publication is made during the Lustrum day of the 20th Engineering Mechanics Symposium. It is printed and handed out at the closing of the event.

www.livemagazines.nl

COLOFON
Release date
24 October 2017
Copyright
Acquisition of images & texts only in consultation with the publisher.
Chief editor / Art direction
Joost van der Steen
Writers
Tracy Brown
Marie-Charlotte Pezé
Catalina Iorga
Mirjam Streefkerk
Graphic design
William van Giessen
Photography
David Jagersma

20th Engineering Mechanics Symposium
Foreword

Today is a special day: the Engineering Mechanics Symposium is celebrating its twentieth anniversary. According to special guest Prof. dr. ir. Frank Baaijens, Rector Magnificus of the Eindhoven University of Technology, that is an impressive feat, as few events of this magnitude have made their mark on the field for so long.

An initiative of the Graduate School on Engineering Mechanics (EM), established in 1996, the Symposium first saw the light of day in 1998, at the beautiful, historical Rolduc abbey in Kerkrade, which Scientific Director of EM and today’s host Prof. dr. ir. Marc Geers jokes that it also had a cold climate in winter. Since 2014 it is hosted here, at Papendal, a large, welcoming modern venue with perfect climate control; but also nightclub-inspired purple LED spotlights, shiny coffee machines and . . . a lot of cake: the perfect setting for a birthday party. As Geers adds, Papendal is the most important sports facility in The Netherlands, which is ‘quite appropriate when you welcome a couple hundred young, dynamic PhD students.’ ‘Science is also a sport!’, he laughs.

It’s a sport which requires incredible commitment from many different branches of the field, all of them represented here today by a couple of hundred attendees. The Papendal’s vast Athene hall is teeming with grad students from local universities as well as faraway places such as Brazil or China, eager to present their PhD projects during the Posters Session. They get to rub shoulders with alumni and professors, guest speakers and lecturers, but also with leading industry companies and lab representatives who are demonstrating the latest developments at the EM Market. Their common goal? Sharing expertise and advancing the field.

The atmosphere is social, joyful even, for this one day of the Symposium that is open to the public. As Baaijens emphasises, the event is ‘all about community building’, and for 20 years, it has monumentally succeeded. Geers is proud of how much EM’s graduate programme and its annual Symposium have fostered and consolidated a strong national network, at the source of many joint projects and discoveries. It has become a beacon of excellence and competence that shines way beyond the Dutch borders, with many of its alumni either joining powerful companies or following brilliant academic careers all over the world, with the noble mission to educate the next generation of engineers.

As Baaijens says, here’s to a fruitful day of scientific exchange – may it last another two decades.
After ten years in the role, Prof.dr.ir Marc Geers is stepping down as Scientific Director of the Engineering Mechanics (EM) Graduate School at the end of the year. He speaks about his experiences in the role, his advice for his successor and hopes for the future of EM.

‘The Scientific Director is essentially the glue that binds the organisation together,’ Geers says. He is quick to add that while he is often the public face of the organisation, it is in no way a one-man operation. ‘It cannot hinge on an individual,’ he says. ‘The school should not be connected to me only.’

Preparing to deliver the opening remarks at the Engineering Mechanics Lustrum – which celebrates twenty years of the EM Graduate School’s delivering PhD education in The Netherlands – Geers is clearly passionate about the school he has played a key role in leading over the last decade.

‘The main mission is to establish a country-wide graduate programme at the PhD level,’ he says. ‘We need to join all the experts from the best schools and create the best programmes. We want to provide top-level education to all our students, no matter which universities they attend. We want all the top experts to participate in providing that education. Students get a lot out of it.’

Geers explains the initiative was a bottom-up one. ‘The community recognised the need,’ he says. ‘And we are fortunate that The Netherlands is a small enough country where this is possible.’

Geers looks around at the Lustrum Day event’s EM Marketplace, which showcases projects, set-ups, equipment, research results and challenges from both academia and industry. ‘If you walk around here in the market,’ he says, ‘you see the wide variety of applications of this discipline. It is not only one discipline, but it has a wealth of applications.’

NEXT GENERATION

In January, Prof.dr.ir Harald van Brummelen of the Eindhoven University of Technology and also a member of the EM board, will take over as the Scientific Director of EM. ‘It should be up to the next generation now,’ Geers says. ‘Ten years is a pretty long time to be in the role, and the school is not dependent on me, or any one person.’

He feels confident his successor will continue to help the initiative maintain its value. ‘Engineering mechanics remains an important field,’ he says. ‘It’s a core branch of engineering.’

Geers is positive the transition will be a smooth one. ‘I wish Van Brummelen a lot of success.’

Prof.dr.ir. Marc Geers reflects on his tenure as EM’s Scientific Director

4

20th Engineering Mechanics Symposium
Koiter lecture:  
The applications of highly stretchy, highly tough hydrogels
What are the possibilities if water is a tough solid? Hydrogels – combinations of a polymer network and water molecules – are solids that retain their exceptional physical and chemical properties. Recent findings support the idea that hydrogels can achieve properties and applications well beyond previously imagined. Prof. Zhigang Suo discusses the possible applications of these highly tough and stretchable materials.

Prof. Zhigang Suo from Harvard University begins the annual, prestigious Koiter lecture by honouring its namesake, Warner Tjardus Koiter. ‘Koiter of course is a giant,’ he says. ‘My own thesis advisor always told me he is the most important person in the field.’

An enthusiastic and entertaining speaker, Suo dives into his presentation. ‘In the spirit of Koiter discovering the world through mechanics,’ he says, ‘the topic today is soft materials and machines.’

HARD AND SOFT MACHINES

Today, he explains, there is an enthusiasm in the community to make a link between hard and soft machines. His first slide displays a human and robotic hand. ‘There is a clear history how soft machines are made,’ he jokes, pointing to the human hand. ‘But now we want to look at how to link a hard machine to a soft one.’

Suo leads a team of engineers at Harvard University to develop new hydrogels that look to have several applications, particularly in the medical community. They may be able to, for example, replace damaged cartilage and act as conductors for artificial limbs.

If you send a signal from your brain to your foot, your foot will move, he offers as an example. Hydrogels could serve to replace copper as the conductor to send such messages to artificial limbs. ‘There are a lot of people who try to persuade you to insert copper wire in your body,’ Suo says. ‘But why not use something closer to the makeup of your own, natural body?’

TESTS OF STRENGTH

Hydrogels are 90 percent water and are highly stretchable, yet tough. They can stretch up to 21 times without breaking. Even if a hydrogel has a crack in it, Suo says, it will not break. They are also transparent, he explains.

He shows his attentive audience some pictures and videos of experiments that tested the strength of the hydrogel. One video is a bit bloody: we see a beating pigs heart in an operation room on which a tough hydrogel patch is stretched and later pulled off. This expensive peeling experiment shows that the tough hydrogel Suo and his team invented is bio adhesive, it can even work inside a body. ‘So we don’t need to put old aerospace materials in our bodies anymore.’

Combing hydrogels with other elements can further strengthen their properties. A picture of alginate, which has the same structure as tofu, shows that a wire cuts straight through it. ‘If you use our tough gel, the same wire can’t get through it,’ he says. ‘It will just spring back.’ The tough hydrogel is also more fire resistant than fabrics that firemen wear, as a video shows. With a smile on his face he says, ‘Now movie actors who do stunts with fire should just put hydrogel on.’

HIGH EXPECTATIONS

In his conclusion Suo compares hydrogel to the evolution of copper, which was used for masks thousands of years ago, later for pans and pipes and for some years as a conductor. ‘Return to mechanics and basic science,’ Suo says. ‘If you believe people will be connected electrically to the world, you need to replace copper wire. Hydrogel was only just discovered, and the expectations for it are high.’

Zhigang Suo is Allen E. and Marilyn M. Puckett Professor of Mechanics and Materials at Harvard University. He earned a bachelor degree from Xi’an Jiaotong University in 1985, and a Ph.D. degree from Harvard University in 1989. Suo joined the faculty of the University of California at Santa Barbara in 1989, Princeton University in 1997, and Harvard University in 2003. His research centers on the mechanics of materials and structures.

Warner Tjardus Koiter (Amsterdam, June 16, 1914 – Delft, September 2, 1997) was an influential mechanical engineer and the Professor of Applied Mechanics at Delft University of Technology in the Netherlands from 1949 to 1979.
Giant Footprints

Many well-trained in applied mechanics still associate The Netherlands with Warner Koiter. Koiter, born in 1914 in Amsterdam, studied Mechanical Engineering at the 'Technische Hoogeschool' in Delft, nowadays the TU Delft. Before being appointed as a professor in applied mechanics at the TU Delft, Koiter worked for the National Aeronautical Research Institute, the Governmental Patent office and the Civil Aviation Office. Koiter became famous with landmark contributions in stability of elastic structures, plasticity and the theory of (nonlinear) shells. However, we also find co-publications in totally different fields, for example, vehicle dynamics.

PHD THESIS

Today, a PhD student typically is hired for a research project, which has a well-defined working plan, milestones and deliverables. In contrast, Koiter had to define his own research topic. After having submitted a rejected research topic, in 1940 his PhD research topic was accepted. In that year the Second World War started and The Netherlands was occupied by Germany. Despite the war, Koiter managed to complete his PhD thesis in 1943. However, the German occupation had huge implications. First of all, there was the limited choice of language. An English thesis was at that time forbidden and the official alternatives were German or Dutch. For very principle reasons, Koiter opted for a thesis written in Dutch. It would have been possible to defend the thesis in 1943. However, a second problem appeared: the occupier required a formal loyalty declaration. Koiter refused to sign this declaration of loyalty, implying that it was impossible to submit the thesis. Koiter’s fully finished thesis was literally on the shelf for two years, awaiting better times! In 1945, as soon as the German occupation came to an end, Koiter defended his thesis. During the post-war years, Koiter was heavily involved in the rebuild of the Dutch aerospace industry and had no time to publish the research in the international literature. The groundbreaking work remained nearly unnoticed for a long time. In the mid-sixties, because of its relevance to aerospace applications, two parallel and independent translations of Koiter’s thesis appeared in the USA. Indeed, mid-sixties, that is more than two decades after finishing the thesis! Despite the enormous delay, Koiter’s PhD thesis is probably among his most important contributions to the applied mechanics field. With his PhD thesis, Koiter paved the way to model efficiently the effects of imperfections in buckling sensitive structures.

SHELLS

After the war, curved thin-walled structures or shortly shells, received major attention from the aerospace industry as fully metal airplanes became standard and large space programmes were ongoing. Shell structures are buckling sensitive and thus triggered Koiter’s interest. Initially, many different shell theories were available, some with inherent flaws, others with highly inconsistent refinements. Koiter provided a major contribution with a comprehensive and precise investigation of existing shell theories and by establishing the rigorous and comprehensive foundations for geometrically nonlinear shell theory.

‘THE READER VERIFIES...’

Most of us will label Koiter’s contributions as fundamental or theoretical. Koiter intentionally collaborated with mathematicians, which led to mathematical rigor. Koiter’s style of writing is precise, but without unnecessary details. Often one may find statements like: ‘The reader easily verifies ... ’. Honestly, be prepared for a multi-page puzzle!

ACADEMIC EXAMPLE

Despite the fundamental character of his contributions, Koiter often stressed that contributions should have a clear application and that it was a responsibility to translate theoretical developments into tools for engineers. Realize, at that time notions like ‘societal relevance’ and ‘valorisation’ were not yet integral aspects of the academic system. To stress his focus on realism and usefulness, Koiter may comment that a study involving an ‘academic example’ would likely imply that a totally useless problem was studied.

GRANT APPLICATIONS

Although Koiter’s research was extremely relevant to industry, most of his research was carried out by himself or with international colleagues. The number of students and PhD students supervised by Koiter is extremely limited, particularly if we compare it to today’s standards. In his farewell lecture, Koiter identified this as one of his shortcomings. In the same speech he mentioned two reasons. First, the high standards he imposed on the quality of the research, likely frightening away potential students. Secondly, he didn’t feel the need for assistance by younger associates. Probably Koiter never wasted costly time and energy in writing grant applications to provide positions for junior researchers and still, mainly on his own, he left giant footprints in the field!

Fred van Keulen
'I’m excited about the marketplace. Although I’ve been attending the EM Lustrum since 2011, I like that there are so many industry people here, so I look forward to connecting to fellow corporate and academic researchers at the many inviting stands and to perhaps test some of the new machines on display’, says Hayo Hendrikse, winner of the 2017 Biezeno Award for the best solid mechanics PhD thesis published in The Netherlands.

And by strolling among dozens of stands, hosted by organisations ranging from oil and gas giant Shell to aviation pioneers Fokker Technologies to the Thermoplastic Composites Research Centre and research university units such as the Delft University of Technology’s (TU Delft) Dynamics of Solids and Structures department, it’s easy to get as enthusiastic as Hajo about innovations that can help industry reduce costs and improve our daily lives.

One great example is Tata Steel’s hot-produced steel grades, which can help make car crashes much less dangerous as this production method reduces damage during impact. ‘Steel is not static at all. It’s an energetic environment where we keep doing research’, confirms Tata Steel in Europe’s Knowledge Group Leader Hans Mulder.

And if steel’s not static, wait till you see what’s happening in energy as collaborative research efforts are helping to radically shape the future of renewables. For instance, Hajo’s ice-induced vibrations research is helping his TU Delft Ocean Energy-focused peers make advances on harvesting energy from ocean currents.

‘Our TU Delft colleagues may be working on different topics, but nonlinear dynamics brings us all together’, confirms Antonio Jarquin Laguna, PhD candidate at the Offshore Engineering Section of the Delft University of Technology. More proof, if needed, that innovation is in connecting the dots with people as passionate as you are about better, stronger and safer materials.
Brilliant minds

From nuclear fusion to biomedical electronics, PhD students are presenting their projects during two different Poster Discussion sessions, each a testament to the vast array of applications that engineering mechanics can contribute to the world.

Awital Mannheim
Eindhoven University of Technology

TOWARDS VIABLE NUCLEAR FUSION REACTORS
To achieve nuclear fusion, we need to mimic the process of the sun on earth. Fusing hydrogen nuclei is much cleaner than using uranium (as we do now), but it’s also an exploit that we’re still a couple of decades away from accomplishing. Located in the South of France, ITER is the world’s largest fusion experiment, with 35 nations collaborating, each bringing its own research and expertise to the project. For her thesis, Awital Mannheim is doing her part, studying the viability of the reactor’s wall. One of the essential components of the wall, the diverter, is crucial: it extracts the heat of the reaction to produce electricity. Made of tungsten (and resistant to temperatures up to 3400° Celsius), that component is subjected to three extreme elements: heat, neutron, and ion loads. Each one of these damages the wall, and Mannheim is hard at work modelling their combined effect on the structure of the material to optimise its lifetime. At a cost of 100 million euros, it’s essential that the wall survives more than two years to be economically efficient. Her research, incredibly, applies to this project and many future others in the field of nuclear fusion.

Gijs Eumelen
Eindhoven University of Technology

SAVING MASTERPIECES
A multi-physics model for damage formation in oil paintings
Gijs Eumelen wants to preserve the great works of art of this world. A continuation of his Masters experiments, his thesis project studies the process by which metal soaps form on top of oil paintings. It is potentially millions of artworks, globally, which are affected by the chemical reaction between the pigments’ oils and metal ions. The bubbles formed continue to grow until they become larger than the paint layers, creating tears and cracks which will ultimately lead to permanent damage of the most famous masterpieces: even Vermeer and Rembrandt’s works are at stake. While he waits for the rare opportunity to get his hands on an actual historical painting, Eumelen is using Abaqus to simulate the bubbles’ growth with numerical modeling. ‘I am the first one to use mechanical engineering to understand this process, which is so remote from the field’, he says, adding that he hopes ‘one day my research will be instrumental in saving many historical treasures’.
Sandra Kleinendorst
Eindhoven University of Technology

CHARACTERIZING STRETCHABLE ELECTRONICS: NOVEL TECHNIQUES
There are many incredible biomedical applications of stretchable electronics, including Sandra Kleinendorst’s research. Done in tandem with Salman Shafqat (in charge of field testing), it aims at creating an inflatable ultrasound sensor which would allow for much more minimally-invasive surgery. ‘We want to bridge the gap between the flexibility of human tissue and the rigidity of electronics’, she explains. Her design, in its fourth year of development, is a marvel of ingenuity. Consisting of a ballooning membrane embedded with image-capturing chips, the device would inflate after insertion in the body and take a vast array of photographs. The electrical wires will need to stretch at least ten times, something that is not possible with the designs currently on the market. To achieve this feat, Kleinendorst has modelled a new type of unfolding wires which are not only free-standing (instead of attached to a rubber surface), but also readily produced in combination with the chips, leading to a one-step manufacturing process. Surgeons using her design will not only be able to reduce the size of incisions, but also benefit from a 3D view of the patient’s organs, giving them a clearer picture of the job ahead.

Eric Simons
Delft University of Technology

SIMULATING IMPACT ON ARMOUR TECHNOLOGY
Eric Simons is studying how to make your armoured car impenetrable. As the field of armoury is moving on from metals to relatively lighter (yet solid as a rock) ceramics, it is faced with the challenge that the material is strong under compression, but brittle under tension. Projectiles will break upon impact, but sometimes so will the armour. The main failure mechanism of ceramics that is witnessed is cone cracking: the material breaks in a cone-like shape, and the angle of that cone is a determining indicator of performance. In brief, the larger the cone, the better your bullet-proof vest. Simons is busy matching his numerical simulations to field tests, in order to investigate which properties of the material, on a very small scale, influence the angle (and therefore the strength): is it the shape of the ceramics’ crystals? Their orientation? TNO does the field testing, and while there is no planned real-world applications yet, the army is sure to be interested in the team’s findings once they are complete.
Sharing impressions

We ask four participants to share their experiences at the EM Symposium.

‘I think this is a great opportunity not only to get to know your peers, but also to get a bigger sense of what’s going on in the Netherlands. As PhD, it’s also a good experience attending conferences.’

*Ines Uriol, (Spain, 27)*
*Delft University of Technology*

‘For me this symposium is the best opportunity to interact with our colleagues from other faculties and universities. And also it gives the chance to generate collaboration... and share some beers!’

*Hector Hernandez Delgado (Mexico, 30)*
*University of Twente*

‘I think what I like is that you’re not only relating to your own project: there are so many different topics related to technology. And it’s nice that you can you build a relationship with people you may never have met otherwise.’

*Irene Scheppeboer (The Netherlands, 26)*
*Eindhoven University of Technology*

‘It’s a great place to learn, network and collaborate with fellow researchers.’

*Jayaprakash Krishnasamy (India, 29)*
*Delft University of Technology*
Alumni lectures:
hydraulic fracturing,
fast computation,
thermoplastic composites

Each year several outstanding alumni are invited to the EM symposium to give the audience some insights into their research topics and career paths. Here they show the range of opportunities in three areas of mechanical engineering.

**Multi-level methods for fast computation**

Garth Wells remembers it well: he presented a PhD poster at the first edition of Engineering Mechanics (EM) in 1997. Wells completed his PhD at the Delft University of Technology and worked there as an associate professor before joining the University of Cambridge in 2007. His alumni lecture today is about Multilevel methods for fast computation.

'As a student I thought I'd be doing experiments; I never thought I'd be doing math,' he says at lunch. 'Now I'm doing a lot of computing, mathematical analyses and things I didn't know anything about when I was studying.'

Wells' reflection on his development is also part of the message he has for new students: 'there are a lot of areas within mechanical engineering, and at events like this you get to learn about all of those different topics. There are opportunities for you in every single area, even in the ones you might not know about yet.'

**Essential Computations**

Many advanced methods Wells will discuss today exploit multi-level representations to wrestle complexity and dimensionality: multi-grid, domain decomposition, neural networks and deep learning are only a few of them. Fast and scalable computations are essential to enabling extreme scale forward simulations, and for methods that require many evaluations of a forward model, such as optimisation and uncertainty quantification.

Wells presents multi-level methods that make fast simulations possible, and thereby make important but intractable problems tractable. He also draws some links from work in these areas to early courses he followed at the Graduate School on Engineering Mechanics (EM). ‘These are links I never anticipated at the time, when I didn’t understand most of the things in the course', he says, smiling.

**Monitoring well development in unconventional reservoirs.**


Since Coenen's talk is at the end of the day — after our deadline — we talk to her about her lecture during lunch. After an academic career and a few years at Dutch research institute TNO, Coenen now is co-owner of Reveal Energy Services, a Statoil Spinoff that helps companies monitoring the hydraulic fracturing process.

'Today I will tell about unconventional wells, reservoirs that, before the introduction of hydraulic fracturing, had insufficient permeability to allow them to flow naturally,' she says. Monitoring the recovery and thus the economic viability of hydraulically fractured rocks is a big challenge for companies, and that is where Coenen’s startup comes in.
BIG SCIENTIFIC CHALLENGES

‘An effective stimulation design can drastically improve the recovery and thus economic viability of a well’, Coenen says. As is stated in the abstract of her lecture, stimulation design poses big scientific challenges for the oil and gas industry. In part because of the large number of design variables, but mostly due to the physical limitations that arise when monitoring experiments that are typically conducted 1 mile underground.

Advances in micro-seismic, tracer technology, fiber-optic and electro-magnetics have already led to new insights. Recent developments demonstrated the feasibility of leveraging principles of poromechanics to monitor the stimulation process, offering an accurate and affordable new technology to the industry, which Reveal Energy Services sells as IMAGE frac. ‘This technology is utilising measurements from surface pressure gauges during the stimulation process to determine the geometry, orientation and spatial location of hydraulic fractures with higher precision than other traditional techniques, while providing insight into the proppant distribution’, Coenen explains.

Thermoplastic composites: slowly but surely

Sebastiaan Wijskamp was a plastics engineering student at the University of Twente when he won a Poster award at the 1999 EM Symposium. After his studies, he worked for a tyre company before jumping at the chance to join TenCate Advanced Composites, the leading Dutch supplier of thermoplastic composites (TPC). For the past two years, he has been a senior research associate at ThermoPlastic Composites Research Centre (TPRC). As he says, his own career has matched the timeframe of developments in Thermoplastic Composites, which really took off in the 80s and 90s. To him, Cogswell’s book ‘Thermoplastic Aromatic Polymer Composites’ (1992), was the trigger for more research in their possible applications, and a raised interest in their industrial applications, especially in the aeronautics and automotive fields. Airbus and BMW are huge fans, for example.

Composed of fiber polymers, TPCs are vastly advantageous over thermoset composites in many ways: the manufacturing process is really fast, it allows for complex shapes and it can be reshaped and cooled down as many times as wished. It’s also highly recyclable, even during the production process where scraps can be immediately re-moulded (something that Fokker is experimenting with at the moment). All in all, TPCs are very attractive, but they are still an immature industry in need of more R&D. At this point, only small secondary parts are being produced with TCP, such as the Airbus 350 fuselage clips. It’s estimated that approximately 5-10% of the aircrafts are currently using TCPs, and the aim of the current research is to use them in primary structures as well. But many aspects of the production process need to be refined; for example, fiber placement is still a challenge because of the creation of voids, and the elimination of large autoclaves is near-impossible at fuselage-building scale. As Wijskamp says, ‘our interest is to understand what happens in the process, and the basic mechanism. There’s still a lot of work to be done in the field, and we need to work on cost reduction of materials and processes. We’re also looking at materials for the future.’ A call to arms if we’ve ever heard one.
Good vibrations: A new theory on what makes structure shake
Launched in 2013 as a Dutch national prize for the best PhD thesis in the field of solid mechanics, the Biezeno Award is awarded annually by the Royal Netherlands Institute of Engineers (KIVI) in cooperation with the Graduate School on Engineering Mechanics (EM). Gerard Hegemans of KIVI and Chairman of the Jury Prof.dr.ir. Dick van Campen of the Eindhoven University of Technology are proud to present the 2017 award to Hayo Hendrikse, Assistant Professor at the Offshore Engineering section of the Delft University of Technology’s Hydraulic Engineering Department. Find out how the new model developed in Hayo’s PhD on ice-induced vibrations is currently helping the wind industry to design better turbine support structures, why working in the Arctic completely changed his outlook and what’s next in his academic career.

How did you decide to focus your PhD project on the aim to create a hybrid multi-scale model of a moving ice sheet dynamically interacting with a bottom founded structure? I had dreamed of becoming a bridge engineer, but then bumped into my supervisor, Prof.dr. Andrei Metrikine, who said ‘This is too boring, definitely not challenging enough for you’. He managed to push the right buttons and I did my MSc project on this topic instead. When the opportunity arose to continue with a PhD, I went for it. The prospect of an Arctic trip, which was part of the project, was also very exciting; had the chance to spend one month on an icebreaker in the Arctic Ocean, in the northeast of Greenland.

In what ways did your experience in the Arctic shape your work? We went to drill holes and measure the strength of the ice in the summer, when you had sun for 24 hours, as doing the same experiments in the darker, colder conditions would’ve been ten times harder. I learned that things you think of behind your desk just don’t work there. For instance, my colleagues wanted to map the area by placing a camera in a balloon attached to the icebreaker, which nearly impossible in foggy conditions, with only one day per week of clear weather. And when it’s minus 20 degrees, handling small screws with gloves on becomes quite a challenge. Especially when, every couple of hours, polar bears come out to play.

What exciting conclusions did you reach with your PhD project? This topic has been studied since the 1950s and the main question had always been ‘what makes some structures shake or vibrate heavily in ice and others not?’ And there were two main theories that had been dominating the field. One theory states that, when ice breaks, its fails with a certain frequency, which creates a resonance effect that explains the vibrations. The other theory assumes that ice offers little resistance when you move fast against it and a lot of resistance when moving slow, which could also account for the structure’s vibrations. But we felt these theories didn’t really fit, so we borrowed the forced vibration test from the field of fluid structure interaction – which is usually performed with cylinders in water – and applied it for the first time to ice studies at the Hamburg Ship Model Basin. Based on the exciting new details we gathered on the contact between ice and a structure, we came up with a third theory, which completely matched our experiments and all previous publically available research on this topic.

We found there’s no constant ice failure frequency and no dependence on strength. What you get instead is a memory effect in the ice: the structure needs a certain amount of time interacting with the ice to develop a larger area and then you get a higher force that makes the structure vibrate.

In what area do you foresee the most valuable applications of your research? When I started my PhD in 2011 the oil prices were high and all fossil fuel companies were joking that they could hire me right away and start building structures in the ice. But then the prices collapsed. Luckily, nowadays you have a thriving market for offshore wind in the Baltic Sea and the Bohai Sea near China. These waters freeze every couple of years, so ice is an important factor to account for in turbine support structure design. We are using the model developed during my PhD to assess the severity of vibrations, which can be quite demanding, and think of mitigation measures based on this model.

I enjoy collaborating with the wind industry. Because they’re working to reduce costs, they calculate everything carefully to optimise turbine structures. In the fossil fuel industry, where you build one-off structures for particular oil fields, you can just reinforce structures with concrete and steel and then you’re certain that they will survive, without focusing too much on details. But the wind industry is very detail-focused and always asks me to dig deeper and keep asking questions.

What’s next for your own work and the field of nonlinear mechanics? I am looking forward to the opportunity to validate my theory with dedicated experiments and real tests in ice. On a European scale, I expect funding to be readily available, especially as countries such as Germany, Finland, Sweden and Denmark are all building offshore wind structures in the Baltic Sea. There’s only so many wind turbines and oil rigs we can build, though, so at some point I will have to diversify and find a new complex puzzle to solve in the field of nonlinear dynamics.

What matters to me is that my research will always have practical applications and help make structures safer. And having my research recognized by independent reviewers is an honour. The award section on my CV had been empty until today, so this will definitely give me a career boost.
What are the most exciting future applications of nonlinear mechanics?

Dr. ir. Rob Fey  
Associate professor at the Eindhoven University of Technology, Member of EM  
'I see micro and nano technology as an exciting future field for nonlinear dynamics, which is my general research area. Some remarkable new developments include our recent collaboration with Philips Research and the Erasmus University Medical Centre on the topic of CMUT (Capacitive Micromachined Ultrasonic Transducers) developed for medical imaging to better detect and diagnose diseases. This is an excellent example of how research in nonlinear dynamics should be carried out. We at TU Eindhoven, a research university, bring our knowledge of modelling and analysis of complex dynamic systems, while Philips, a corporate, has the ideal experimental setup to validate our analysis and Erasmus University Medical Centre supplies doctors eager to use CMUT to help their patients. We also started collaborating with TNO’s Hamed Sadeghian, who is very much involved in nanotechnology. Together, we want to develop nano hammering using AFM (Atomic Force Microscopy). That would be a groundbreaking achievement in creating nano structures.'

Dr. ir. Semih Perdacioglu  
Assistant Professor at the University of Twente, Member of EM  
'My work aims to innovate material modelling that helps describe the mechanical behaviour of metal, which is currently stuck with a 1950s approach. We know that microstructures play a crucial role in how metal sheets are formed or deformed, so observing the results of as many phenomena as possible through microscale experiments is crucial for developing reliable physical models to predict what would occur at macroscale. In its quest to develop increasingly complex, lighter and safer materials, the industry is becoming more curious about microscale phenomena. And the broad application spectrum of our research includes projects with industry players such as Tata Steel and Philips, and spans everything from razors to auto bodies and industrial equipment. A particularly important use is in preventing fractured metal, such as detecting steel that’s already damaged and ready to break in the unfortunate case of a collision. What we do could thus help reduce and avoid the massive impact of car crashes.'

Dr. ir. Matthijs Langelaar  
Associate professor at the Delft University of Technology, Member of EM  
'In my work, I use computer models and algorithms to optimise design functionalities for additive manufacturing. This type of manufacturing allows you to print all kinds of geometries, but metal printing, for instance, has its share of limitations. Such models are quite challenging – we have to make hundreds of steps, but keep the simulation and accurate, capable of providing meaningful information. One area I’m currently examining comprises the thermomechanical effects of additive manufacturing. Take, for instance, a complex metal component where many tubes come together. The conventional way to produce it is to makes holes and then connect the tubes, but printing allows you to create it exactly as you want it from the get go. And that includes molten material that solidifies and cools down, so our models help predict the final shape of the product. This could impact industries such as the aerospace sector, which is pushing additive manufacturing to print light and cheaper frames for satellites, for example. Thanks to their ambition and support, design tools are progressing at a faster rate and the certification of parts for flight might be catching up soon.'
Some historical notes on the Graduate School on Engineering Mechanics

The Graduate School on Engineering Mechanics was founded in 1996 and has been accredited by the Royal Netherlands Academy of Arts and Sciences (KNAW) since 1997. The School embraces all internationally important Solid Mechanics research groups at the three technical universities of Eindhoven, Delft and Twente. The prime objective of the Graduate School over the past twenty years was to establish a national high-level scientific education of PhD students and Post-Docs. Supported by its constituting research groups, several generations of highly-qualified independent researchers in the field of Engineering Mechanics have been trained.
The foundations for the Graduate School Engineering Mechanics were laid in autumn 1994, when a ‘National Platform on Engineering Mechanics’ was launched with the goal to establish, including accreditation, a national graduate school in engineering mechanics. The members were Johann Arbocz, René de Borst and Erik van der Giessen, all from the Delft University of Technology, Henk Tijdeman from the University of Twente, and Dick van Campen from the Eindhoven University of Technology. Dick van Campen acted as chair and secretary.

The EM Platform worked efficiently, and in spite of some initial political head wind from the Boards of some of the participating universities, early 1996 the format of the EM Graduate School was established. On the one hand a set of basic research themes of the EM Graduate School were defined, while on the other hand, a graduate course program was developed for the PhD students of the EM Graduate School. At a national level, these were radically new developments.

A structure was set up, with the Eindhoven University of Technology acting as the commissioner, hosting the EM secretariat. The roles of EM Scientific Director and EM Chairman of the Board were distributed over different universities. This structure worked successfully over the years, which was largely dependent on good personal relations.

By the end of 1996 the documents for formal accreditation were signed by the Boards of the participating universities and departments, and were submitted to the Royal Netherlands Academy of Arts and Sciences (KNAW). In June 1997 accreditation was approved by the KNAW for a first five-year period, and was renewed in 2002, in 2007, and in 2013.

On 23rd September 1997 the EM Graduate School was inaugurated with a symposium at the Eindhoven University of Technology. Contributions from the three participating universities surveyed the ongoing research and interactions between different groups.

The first four-year cycle of EM graduate (PhD) courses started in 1998. In order to adapt to national and international developments, the structure of the EM graduate course program was fundamentally renewed and extended in 2008.

Upon launching the EM Graduate School, it was decided to start a series of annual two-day EM Symposia for the PhD students and staff of the EM Graduate School, the first one in the series having been organized in November 1998. An initial lay-out of the EM-Symposia was designed, which proved successful and was broadly adhered to over the years, of course with relevant adaptations and improvements.

Characteristic for the lay-out of the EM Symposia are:

- An Opening Lecture by an internationally renowned scientist in the engineering mechanics field, from the 14th EM Symposium (2011) onwards the called the Koiter Lecture, named after Professor Koiter, an internationally renowned founding father of engineering mechanics in the Netherlands.

- Four carefully selected Topical Sessions, renamed Workshops from the 5th EM Symposium (2002) onwards.

- A Poster Discussion Session, where current research projects carried out by PhD students of the EM Graduate School are presented and discussed, including a Poster Contest.

- Various meetings of EM staff members, as well as a meeting of the EM Advisory Board, which has given invaluable advice over the years.

The first seven EM Symposia (1998-2004) took place in Rolduc, a medieval monastery transformed into a conference center close to Kerkrade. Rolduc was famous for its ambiance, but less well located, especially for the Delft and Twente participants. Hence, from 2005 till 2013 EM Symposia were held at De Werelt, located much more centrally in Lunteren. Since 2014, the conference center of the national sports complex, Papendal, in the outskirts of Arnhem, has been chosen as the location for the annual EM Symposia.

The existence of the EM Graduate School has been crucial for the visibility and importance of engineering mechanics nationally and internationally. Its establishment has been an enabler of the following major initiatives:

- The establishment in 2005 of a Centre of Excellence (CoE) in Fluid and Solid Mechanics as one of the five CoEs of the Netherlands Federation of Technical Universities.

- The approval (2007) of a Research Program in Multiscale Simulation Techniques, by the Technology Foundation STW. Through this program and including industry contributions, it has been possible to finance 19 PhD positions.

- The approval (2011) of a national Graduate Program in Fluid and Solid Mechanics by the Netherlands Organization for Scientific Research.

- The launch in 2013 of a national prize for the best PhD thesis in the area of solid mechanics. This prize, named the Biezeno Award after another founding father of engineering mechanics in the Netherlands, is awarded annually by the Royal Netherlands Institute of Engineers (KIVI) in co-operation with the EM Graduate School.

In sum, the EM Graduate School has been pivotal for profiling engineering mechanics as a crucial and indispensable basic engineering science in the Netherlands.

Eindhoven and Sheffield, 11 October 2017
Dick van Campen and René de Borst

20th Engineering Mechanics Symposium