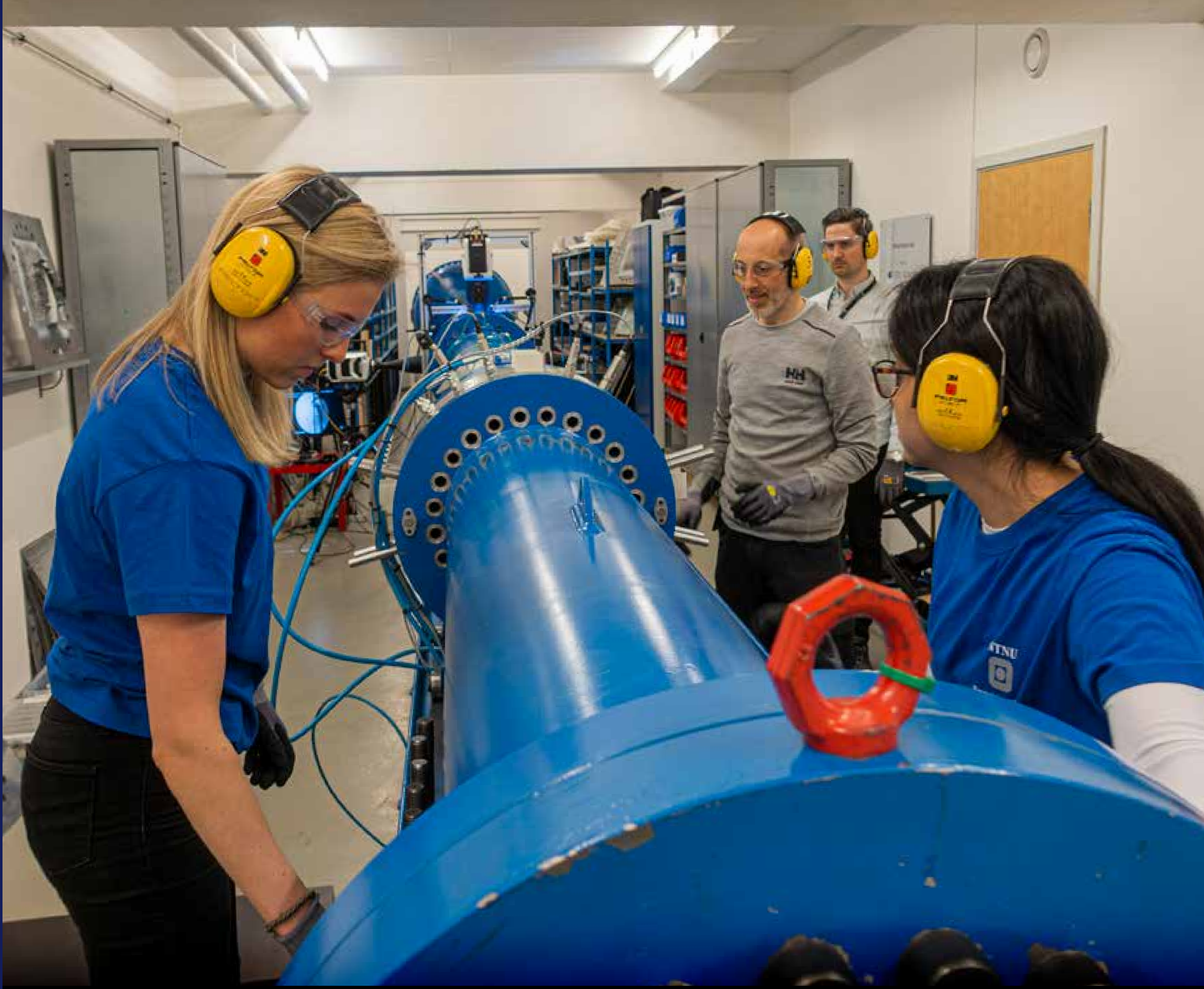
CASA

Annual Report 2021

Centre for Advanced Structural Analysis



sfi Centre for Research-based Innovation

SINTEF

NTNU

NORWEGIAN NATIONAL SECURITY AUTHORITY

Norwegian Ministry of Local Government and Regional Development

Statens vegvesen

Audi

BMW

RENAULT

HONDA

DNV

Multiconsult

BENTELER Automotive

equinor

FORSVARSBYGG

Hydro

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COVER:
MSc students Ingrid Gisnås (left) and Ayesh Syed performing a test in SIMLab´s Shocktube assisted by Senior engineer Trond Auestad and Associate Professor Vegard Aune. The title of the student´s thesis is «Dynamic response of flexible structures subjected to blast loading». (Photo: Sølvi W. Normannsen)

GRAPHIC DESIGN:
Sølvi W. Normannsen/NTNU Grafisk senter

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THE DIRECTOR´S SUMMARY

Tales of PROTECTION

Imagine a strand of hair. Then, try to imagine something as thin as the thousandth part of that strand of hair. That is the size of the smallest blocks in aluminium and steel, which are among the favourite materials for engineers and architects in the automotive and construction industries.

We all know that the devil is in the details. Damage always starts in the microstructures when materials fracture and buildings collapse. Therefore, these tiny building blocks are SFI CASA's starting point. At the same time, our overall goal is increased safety for people and vital infrastructure. If the worst happens, you must have as much protection as possible, whether on an oil rig, in a car, a building or a space capsule.

In 2021, we arranged 2 doctoral dissertations. Daniel Thor Morton defended the first-ever PhD thesis on polymer foams within SFI CASA in June. Polymer foams are frequently used in car bumpers. They are exceptionally lightweight and possess a unique ability to absorb energy. Ideally, bumpers should behave in the same way, whether a pedestrian is hit in cold northern Norway or in hot Spain. Morton has developed a methodology for simulating how polymer foams react to impact at different speeds and at different temperatures.

Jianbin Xu also defended his thesis in June. He has been researching a phenomenon that has created headaches for aluminium producers and researchers for more than 100 years. The so-called Portevin-Le Chatelier (PLC) effect that can occur because of alloying. This process is intended to strengthen the material. Instead, the PLC effect causes the metal to deform inconsistently. When this happens, it can lead to poorer ductility, meaning the ability of a material to bend or stretch before it cracks or fails. Jianbin Xu's work contributes to help us understand more of the phenomenon and hopefully brings us closer to the day when we can understand it completely.

In addition to studying individual materials, we also model the behaviour of the joints connecting materials. This is a significant challenge for the automotive industry, as new cars consist of numerous small and large parts in different materials. Some are welded, some are glued, and others are joined together with self-tapping screws and rivets. Some of the most extensive simulation programs in the world, such as LS-DYNA and PAMCRASH, include more and more of the models that CASA develops. This means that the Centre helps improve tools used by industry worldwide.

The technology developed in the Centre is generic and can therefore be used in various areas. The models make it possible to change the chemical composition and treatment all the way down to the nano level. Hydro uses the technology to find ideal aluminium alloys for different customers.

Protection is always weighed up against usability, as in the new Norwegian Government Quarter, where glass facades will be extensively used. The client is the Norwegian Ministry of Local Government and Regional Development.

We collaborate closely with partner Norwegian Defence Estates Agency. Our joint effort is to develop, and quality assure a material model that allows NDEA to run simulations of projectiles that penetrate concrete.

In autumn 2021, we put full-scale sections of pipelines from Johan Sverdrup Field in the North Sea through tough testing. The pipelines carry oil and gas along the seabed and must endure significant stress. One recurring challenge is the impact of ship anchors or gear from fishing trawls. The research team investigate how the concrete coating on the pipe contributes to energy absorption during such impact incidents.

CASA's laboratory (VL) for virtual testing of aluminium is soon complete. We have ongoing work on a similar lab for steel. VL has become a powerful tool that can reduce the time spent in a single production process from 2 months to 24 hours. The industries that use the models save time and money, and at the same time, achieve safer solutions. Our research contributes to more aluminium in cars, which reduces weight and fuel consumption. When crash tests on a PC replace physical testing, the outcome is less waste, reduced emissions and increased sustainability.

SFI CASA has been involved in Statsbygg's project to develop a new movable vehicle security barrier system. The project is called an innovation partnership, which includes purchasing if the innovation is successful. The barriers will protect the new Government Building Complex in Norway. The backdrop is terrorist attacks where vehicles have been used as weapons. The barrier system must adapt to the challenging and shifting Nordic climate. Also, there is a strong need to create a government quarter that is open, inviting and safe.

PhD candidate Rannveig Marie Færgestad literally takes the research in CASA to a new level. She was an MSc student in the spring, and her doctoral work continues her MSc thesis. The topic is hypervelocity impact from space

> When crash tests on a PC replace physical testing, the outcome is less waste, reduced emissions and increased sustainability

debris which is an extensive and growing security problem in lower space orbits. Fragments from meteors or colliding satellites turn into projectiles hurled around at a speed of 10-20 kilometres per second. Færgestad's goal is to improve and develop models that can help protect structures in space.

After submitting a written contribution to the public hearing on the Parliament's white paper on societal security, CASA attended Parliament's open hearing on the topic in January. CASA also got valuable attention from the country's top rostrum when the politicians debated the white paper. In May, we met Henrik Asheim who was then the Minister of Research and Higher Education. As part of the Long-Term Plan for Research and Higher Education (LTP) work, the Minister wanted to learn how SFI CASA helps its industry and other partners use our research. We also provided input to the LTP and the Research Council's Portfolio plan for natural science and technology.

Our industry partners continue to follow us closely and contribute actively to our research. The Centre is nearing the end of its allotted SFI period in 2023. We can assure you that we will keep up the efforts to secure continuation in some form and maintain our world-leading position within our field.

Magnus Langseth

Centre Director

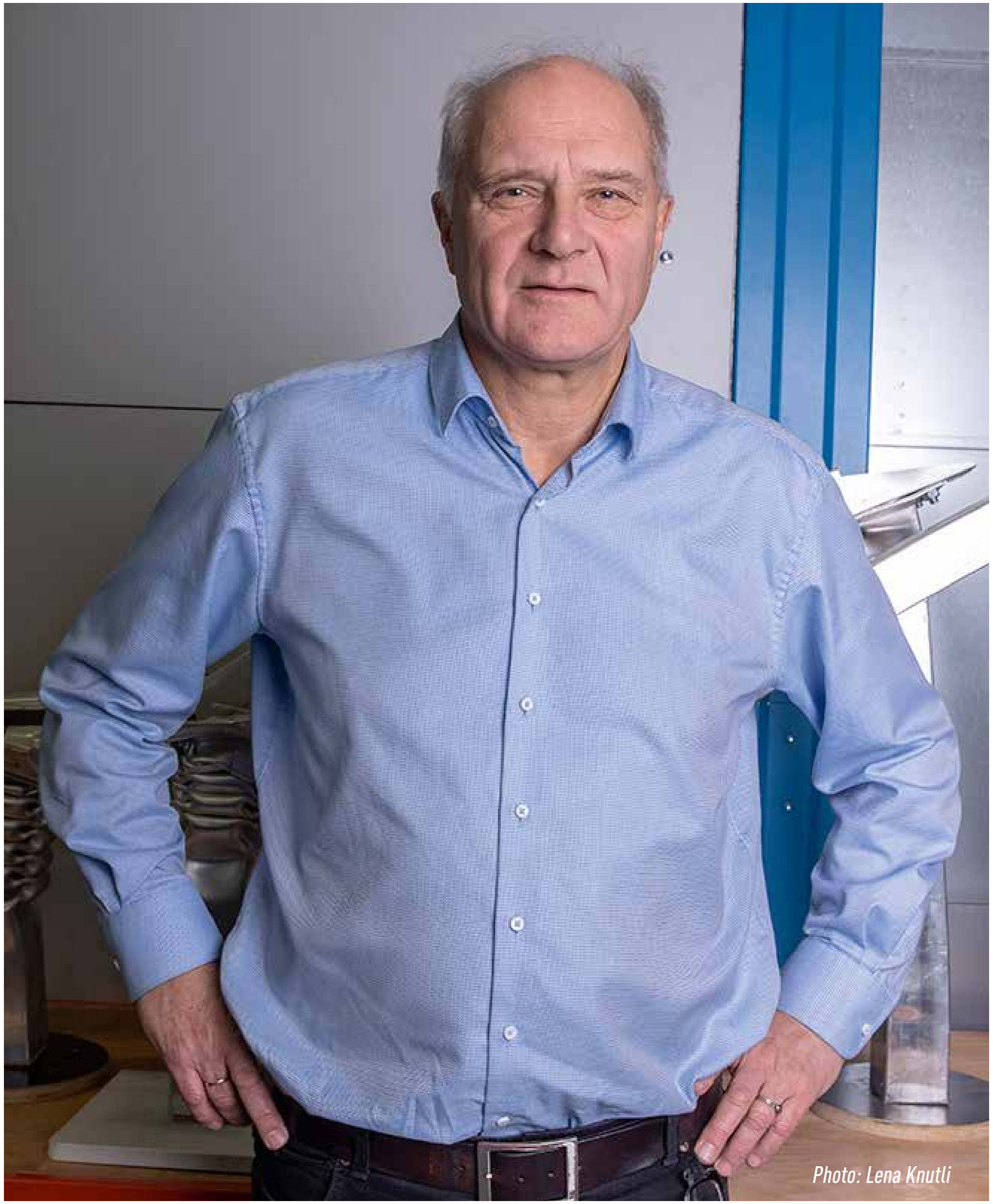

Photo: Lena Knutli

ABOUT CASA AND 2021 IN BRIEF

Hearing in Parliament

On 19 January, The Standing Committee on Justice hosted a hearing in Parliament regarding the Norwegian Government's new white paper on societal security. SFI CASA´s director Magnus Langseth was among the participants who publicly shared their views with politicians.

According to Professor Langseth, Norway still has a way to go in its work with preventive physical security. He said that the Government relies on inadequate regulations. Also, he argued that the white paper lacked guidelines about how to establish a national set of rules that can protect civilian buildings and structures and, thus, people´s life and health. Professors Magnus Langseth and Tore Børvik published a chronicle on the same topic in the Norwegian newspaper Adresseavisen.

The new Security Act from 2019 plays a crucial role in the white paper. The law requires that all companies with potentially exposed objects and infrastructure must themselves assess risk and ensure sound security. Langseth states that the law requires a level of comprehensive competence that most companies lack. Their most important tool is the current Norwegian standards. However, the standards state almost nothing about the principles for calculating the response from loads such as explosions, shocks, collisions and shelling. Professor Langseth concluded that it is very demanding for companies that have to comply with the new Security Act to find people with the right competence to advise them.

History

The activities in SFI CASA are based on the research platform generated in the SFI SIMLab centre from 2007-2014. They preserve and develop further the knowledge and infrastructure generated by an investment of NOK 225 million to facilitate innovation and value creation in important business areas for Norwegian society. CASA is much broader in scope than the previous centre as it is based on multi- and interdisciplinary research on different physical scales.

Organization

CASA (Centre for Advanced Structural Analysis) is a Centre for Research-based innovation (SFI). It is hosted by the Department of Structural Engineering at the Norwegian University of Science and Technology, in close cooperation with Department of Materials Science and Engineering and Department of Physics, also at NTNU. SINTEF Industry is the research partner. In addition to NTNU and SINTEF, the consortium includes 13 industrial partners. SFI CASA's board comprises one representative from each partner. A director heads the daily operation, assisted by a core team and programme heads. CASA's Industrial Reference Group monitors and facilitates industrial implementation of the results generated in the Centre. Our Scientific Advisory Board of 8 international experts provides scientific and strategic advice.

Research plan

The Centre's research is organized in five basic research programmes: Lower Scale, Metallic Materials, Polymeric Materials, Structural Joints, and Structures. The programmes Methods and Tools and Industrial Implementation focus on the transfer of knowledge and technology from the research programmes to the industrial partners.

Meetings, seminars, and conferences

The Centre organized several online seminars and lectures through 2021 to spread knowledge about the research done in the research programmes. The research is based on annual work plans generated on the basis of discussions between the partners, in technical meetings, and in the Industrial Reference Group. The Industrial Reference Group met online on 31 August. The Board have had 2 meetings on Teams, on 26 May and 10 November.

International cooperation

International cooperation and leading-edge research are fundamental to an SFI. The key researchers in CASA all have an extensive international network. Three of the professors are editors of leading international journals. The Centre cooperates with several research institutions and companies worldwide. In addition, the Centre has four international partners (Audi, BMW, Honda, and Renault).

Visibility

SFI CASA has a media strategy for popular scientific presentations of its research. CASA also aims to contribute to a knowledge-based, open public debate. In that respect, the Centre director has been visible in 2021. It is also our aim to make female researchers and profiles particularly visible to recruit women and contribute to a more even gender balance in this research field.

In 2021 the research group has employed two new female PhD candidates and one new female post doc.

Visibility in the research community is also important. The CASA researchers published 16 journal articles and they gave 20 conference presentations. In addition, concurrent projects hosted by the research group published 9 journal articles and gave 3 conference presentations.

PhD defences

2 PhD candidates defended their theses in 2021: Daniel Thor Morton and Jianbin Xu.

Vision

To establish a world-leading centre for multiscale testing,modelling and simulation of materials and structures for industrial applications

Objective

The Centre will develop validated computational tools for innovation together with and for partners in the oil and gas industry, the transportation industry, and in industry and public enterprises working with physical security. Thus, our partners work with critical infrastructure offshore, automotive and infrastructure along Norwegian roads and with protection of critical infrastructure that could be subjected to terrorist acts and sabotage. They represent different business sectors, but have similar needs in advanced structural analysis. Simply because the underlying theories and formulations behind the different computer tools are the same. Accordingly, the basic research in the Centre is precompetitive and generic in nature to facilitate cooperation between the user partners and hence transfer of knowledge across business sectors.

This supports the success criteria defined by the Research Council of Norway for an SFI centre where research at a high international level aims to create a platform for innovation and value creation. Our major research initiative is only achievable for a centre with long-term objectives and funding.

Thus, CASA´s main objective is:

To provide a research and technology platform for the creation and development of smart, cost effective, safe, and environmentallyfriendly structures and products through multiscale testing, modelling and simulation.

SLADE KPN: Slamming tests on small-scale models in the SINTEF Ocean Basin Laboratory. Rene Kaufmann (sitting)) and fellow researcher , SINTEF´s Bjørn Christian Abrahamsen (Photo: Vegard Aune).

Research Questions:

RQ1:
How can we establish accurate, efficient and robust constitutive models based on the chemical composition, microstructure and thermo-mechanical processing of a material?

RQ2:
How can we apply knowledge of materials, geometry and joining technology to obtain optimal behaviour of hybrid structures for given load situations?

RQ3:
How can we describe the interaction between the load and the deformable structure under extreme loading scenarios?

Motivated by these research questions, five basic research programmes are defined in order to increase the prediction accuracy of numerical simulations under quasi-static and impact loading conditions.

Industrial Goals:

- To develop methods and tools for implementation at the user partners.
- To ensure the transfer of technology across business sectors.
- To arrange courses and case study seminars at the user partners.
- To facilitate concurrent research projects with the user partners and cooperation between partners.
- To facilitate employment of post docs, MSc and PhD candidates at the user partners to strengthen the industrial implementation.

Academic Goals:

- To graduate at least 20 PhD candidates and employ 5-10 post docs at the Centre.
- To graduate 100-200 MSc students.
- To attract 5-10 non-Norwegian professors/scientists to the Centre.
- To publish 100-150 papers in international peer-reviewed journals in addition to conference papers.
- To arrange two international conferences.

Media Goals:

- To implement a strategy for popular science presentations of the research activities in magazines, newspapers, on television, radio and the web.
- To establish a media strategy where female researchers are made particularly visible in order to recruit female PhDs and post docs and contribute to a more even gender balance in this research field.

Safety at SEA

Severe storms can cause steep and violent waves slamming into platforms and offshore wind turbine structures. In the SLADE KPN project, SIMLab's postdoc Rene Kaufmann is measuring the pressure and deformations from such massive loads. In June, Kaufmann and fellow NTNU and SINTEF Ocean researchers performed slamming tests on small-scale models in the SINTEF Ocean Basin Laboratory.

«It is crucial to understand the mutual interaction between the impacting wave and the response of the structure», says Kaufmann. His background is in fluid mechanics, and he is an expert in deflectometry. Kaufmann describes this as a full-field surface slope measurement technique. It is sensitive and allows the measurement of deformations down to the micrometre level.

Wave slamming can cause massive damage. Offshore platforms and rigs, wind turbine towers, ships, or other sea structures are at risk. The accurate prediction of structural response is one of the fundamental – and unresolved – problems in designing such large ocean structures. Solving these will be a great step towards safer and more cost-efficient marine operations. The path goes through systematic experimental studies of relevant wave-impact scenarios, combined with the development of experimental, numerical, and analytical methods.

SLADE KPN manager, Dr Øyvin Hellan, describes the project as an inspiring collaboration between complementary world-leading research environments: SINTEF Ocean, NTNU´s Department of Marine Technology and SIMLab.

RESEARCH PROGRAMMES

Lower Scale:

This programme concentrates on the lower length scales of materials, from atomic up to the micrometre scale, and will provide experimental and modelling input to the multiscale framework from the lower scale.

Metallic Materials:

This programme develops a physically based and experimentally validated multiscale framework providing constitutive models for crystal plasticity, continuum plasticity, damage and fracture of metallic materials. The main emphasis is on aluminium alloys and steel. In many critical structural applications, material properties beyond standard testing conditions are required; hence, there is given special attention to high and low temperatures, high pressures (from blast waves or water depths) and elevated rates of strain (including shock loading).

Polymeric Materials:

This research programme develops and improve material models representing the thermo-mechanical response up to fracture for polymers, i.e., thermoplastics with or without fibre-reinforcement and elastomers. The models are developed for application in an industrial context. Particular attention is paid to validation and efficient identification of the parameters involved in the models.

Structural Joints:

This programme provides validated computational models for multi-material joints applicable in large-scale finite element analyses. The scope is limited to the behaviour and modelling of structural joints made with screws, adhesive bonding and self-piercing rivets – as well as possible combinations of these. The considered materials are steel, aluminium and reinforced polymers.

Structures:

This research programme develops advanced computational tools and establish validated modelling guidelines for computer-aided design of safer and more cost-effective structures. Another objective is to replace phenomenological models with physical models in a top-down/bottom-up multiscale modelling approach in order to reduce the number of mechanical tests as much as possible in the design phase. With respect to protective structures, the emphasis in this research programme is to move away from traditional fortification installations and focus on innovative lightweight and hybrid structures to meet the future needs of the user partners. Materials of interest are those typically used in protective structures, such as steel, aluminium, polymers, glass, foams, ceramics and concrete.

BEST Educator

Professor Odd Sture Hopperstad has impressed his students with his outstanding pedagogical skills. Now it was time to honour his exceptional efforts to convey advanced and theoretical knowledge in a rewarding and understandable way. On 2 November, Hopperstad received the Norconsult award for best educator at Civil and Environmental Engineering at NTNU.

«This award came as a delightful surprise to me. I am thrilled to get such recognition among so many good nominees», Hopperstad said.

The Jury states that the students have been very impressed with how he has established an entirely new -and hefty- compendium for the new subject Mechanics 4. The Professor has «delivered the lectures very orderly, with remarkable commitment, active discussions, outstanding pedagogical skills and active checking on whether the students have understood the content».

The Jury also emphasizes the excellent collaboration between the Professor and PhD candidate at FractAl, Vetle Espeseth. «There should have been an award for the best research assistant as well. Then, Espeseth should have had it», Hopperstad said.

The Norconsult award aims to stimulate and highlight the importance of educational activities. Also, it plays a role in recruiting students and achieving high-quality graduates. The Jury´s reasoning states that Hoppestad's work in a new teaching theme took place during the demanding era of COVID-19 with online teaching.

In spring 2021, MSc student Tameem Karim Pathan (left) worked on optimization of extruded aluminium profiles for battery tray protection in electrical cars. Here, Research Scientist Martin Kristoffersen (in the middle) and Professor Odd Sture Hopperstad monitor a lab test (Photo: Sølvi W. Normannsen)

RESEARCH METHODOLOGY

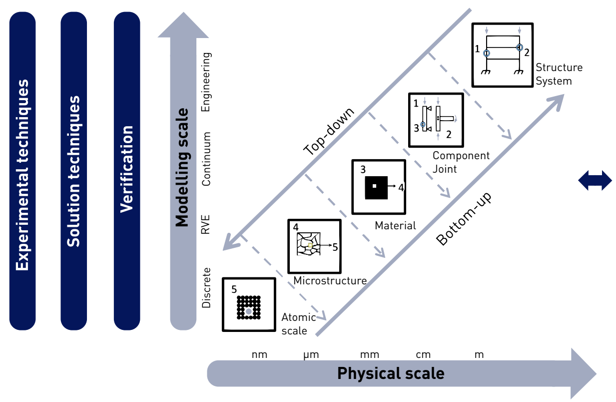

Figure 1: Research methodology.

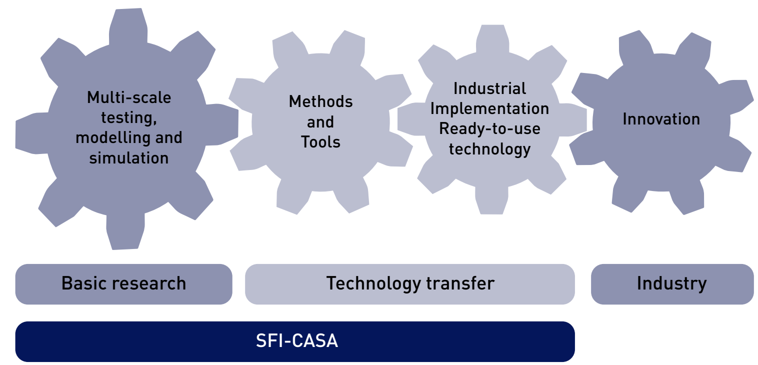

Figure 2: Structure of research, technology transfer and industrial implementation.

The activities in CASA represent a step change for advanced structural analysis for industry and public enterprises as it is based on multi- and interdisciplinary research on different physical scales. The research methodology adopted to meet the overall objective is presented in Figure 1.

As illustrated, a structure or product can be studied on different physical scales just like the modelling scales (there is also a time scale which reflects the duration of the physical events to be studied, but this is not shown in the figure). By using a top-down/bottom-up approach the main goal of the research will always be the final structure or product. In some cases, microstructural modelling or even modelling on atomic scale may be required to understand the underlying physical mechanisms of the observed material response to loading, whereas for joints or components the behaviour may be suffi ciently well understood on the continuum scale. In all cases, research at the Centre is designed to obtain modelling frameworks on the material and structural levels that are suitable for industrial applications. Many research topics and activities are addressed on the various scales: testing and modelling of materials and structures, numerical solution techniques, experimental techniques, verifi cation and validation approaches, and optimization methods and parametric studies. Verification is the process of determining that a computational model accurately represents the underlying mathematical model and solution, whereas validation deals with the relationship between the computational model and the physical reality.

Figure 2 illustrates the important interlink between Basic research, Technology transfer and Industry. The Methods & Tools programme is a synthesis of Basic research, where guidelines and recommended practice for credible numerical structural analysis is established. The Industrial implementation programme is the link between the Methods & Tools programme and the industrial use of the research and technology developed at the Centre for innovation.

The overall management structure of the Centre is shown in figure 3. The Centre consists of a board comprising members from the consortium participants. The Board's mandate is to formulate the strategy for the Centre, approve annual operational plans, monitor the performance of the Centre according to the performance indicators described in the project description and annual targets, and propose corrective actions when needed. The Centre director leads the operation of the Centre, assisted by a core team. A Scientific Advisory Board of international experts provide strategic advice. Each of the five research programmes is led by a programme head. These programme heads are responsible for the validation of the developed models and technology. Cooperation across the research programmes ensures the transfer of technology and allow possible synergies. The Methods & Tools programme is the main instrument to link the research programmes in the Centre and the Industrial implementation at the industrial partners. These activities are also led by programme heads. The Centre has a clear strategy for the management of intellectual property issues, including any assignment for commercialization or development and the distribution of any commercial returns.

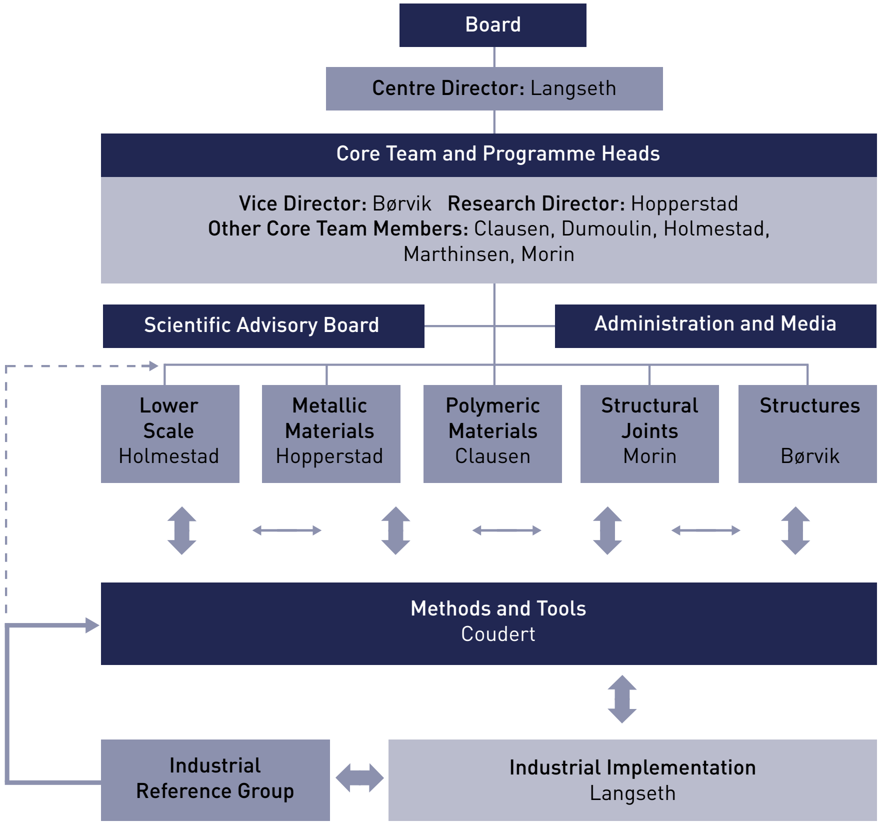

Figure 3: Structure of the organization in 2021

Meeting the MINISTER

The then Minister of Research and Higher Education Henrik Asheim paid a digital visit to SFI CASA on 25 May.

«It was very inspiring. We need more results from research, in line with what CASA has achieved», he said after the visit.

The backdrop was that the Ministry of Research and Higher Education had started their initial work on revising the long-term plan for research and higher education (2019-2028). This plan is one of the most important strategic tools in Norwegian knowledge policy. The main goals are to strengthen the country's competitiveness and ability to innovate. Further, the plan should meet significant societal challenges and develop professional environments of outstanding quality. When the Ministry was looking for an example of a research project that illustrates the plan's goals, SFI CASA came up as an ideal place to visit.

Director Magnus Langseth presented the Centre's achievements. Afterwards, he and the minister discussed the importance of close collaboration between researchers and industry.

«In the work on the long-term plan, we must make sure to couple the substantial public funding of research to the needs of the industry and working life. This interplay is what we will live off in the future», Asheim said in an interview with the University Newspaper at NTNU.

He also said he found it «very useful to listen to CASA pointing out that money allocated to research should result in something that the industry can use».

Scientific Advisory BOARD


Ahmed Benallal


John Hutchinson


Patricia Verleysen


Jonas Faleskog


David Embury


Stefanie Reese


Norman Fleck


Stefan Hiermaier

The Board

Anders Artelius, Benteler Automotive Raufoss AS
Olav Bolland, NTNU (Chair)
Ole Daaland, Hydro Aluminium AS
Eric DeHoff, Honda R&D Americas, LLC.
Cato Dørum, Norwegian Public Roads Administration
Anders Haavik-Nilsen, Norwegian Defence Estates Agency
Agnes Marie Horn, DNV AS
Håvar Ilstad, Equinor Energy AS
Rolf Skåre-Jullum, Ministry of Local Government and Regional Development
Sebastian Kreissl, BMW Group
Christopher McCabe, Norwegian National Security Authority
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Professor Stefan Hiermaier, Ernst Mach Institute, Germany
Professor John Hutchinson, Harvard University, USA
Professor Stefanie Reese, Aachen University, Germany
Professor Patricia Verleysen, Ghent University, Belgium

Centre Director

Magnus Langseth, Professor, Dept. of Structural Engineering, NTNU

Core team and programme heads

Tore Børvik, Professor, Dept. of Structural Engineering, NTNU
Arild Holm Clausen, Professor, Dept. of Structural Engineering, NTNU
Térence Coudert, Research Scientist, SINTEF Industry
Stéphane Dumoulin, Research Scientist, SINTEF Industry
Randi Holmestad, Professor, Dept. of Physics, NTNU
Odd Sture Hopperstad, Professor, Dept. of Structural Engineering, NTNU
Knut Marthinsen, Professor, Dept. of Materials Science and Engineering, NTNU
David Morin, Associate Professor, Dept. of Structural Engineering, NTNU

Scientific staff

Vegard Aune, Associate Professor, Dept. of Structural Engineering, NTNU
Torodd Berstad, Researcher, Dept. of Structural Engineering, NTNU
Miguel Costas, Associate Professor, Dept. of Structural Engineering, NTNU
Virgile Delhaye, Senior Research Scientist, SINTEF Industry
Egil Fagerholt, Researcher, Dept. of Structural Engineering, NTNU*
Martin Kristoffersen, Researcher, Dept. of Structural Engineering, NTNU
Calin Marioara, Senior Research Scientist, SINTEF Industry
Inga Gudem Ringdalen, Acting Research Manager, SINTEF Industry
Afaf Saai, Senior Research Scientist, SINTEF Industry
Ida Westermann, Associate Professor, Dept. of Materials Science and Engineering, NTNU

*20% position at NTNU

Other Key Personnel

Trond Auestad, Senior Engineer, Dept. of Structural Engineering, NTNU
Peter Karlsaune, Project Coordinator, Dept. of Structural Engineering, NTNU
Sølvi W. Normannsen, Communication Officer, Dept. of Structural Engineering, NTNU
Linda Katalin Veres, Accountant, Dept. of Structural Engineering, NTNU
Tore Wisth, Senior Engineer, Dept. of Structural Engineering, NTNU

Partners in 2021

Host institution

NTNU

Research partner

SINTEF Industry

Industrial partners

Audi AG
Benteler Automotive Raufoss AS
BMW Group
DNV AS
Equinor Energy AS
Honda R&D Americas, LLC
Hydro Aluminium AS
Ministry of Local Government and Regional Development
Multiconsult Norge AS
Norwegian Defence Estates Agency
Norwegian National Security Authority
Norwegian Public Roads Administration
Renault

CASA Core team and administrative personell. *1st row from left: Knut Marthinsen, David Morin. 2nd row from left: Sølvi Marie Waterloo Normannsen, Tore Børvik, Randi Holmestad, Terence Coudert. 3rd row from left: Arild Holm Clausen, Odd Sture Hopperstad, Peter Karlsaune, Stéphane Dumoulin, Magnus Langseth (Photo: Ole Martin Wold).*

COOPERATION WITHIN THE CENTRE

The research done in CASA is based on annual work plans based on the project description in the SFI CASA application, previous work, and discussions with the industrial partners.

SFI CASA's Industrial Reference Group (IRG) met online on 31 August. Each industrial partner has one member in the IRG, whose mandate is to give advice on how implementation should be facilitated and to evaluate the implementation work at each partner.

The research in the Centre is mainly carried out by NTNU (PhD candidates, post docs, scientists and professors) and SINTEF (scientists) personnel. The main contribution from the partners is to guide the direction of the research to be carried out and to be active in the implementation of the technology. Norwegian Public Roads Administration and Hydro Aluminium AS are sponsoring one Adjunct Professor position each at the Department of Structural Engineering, NTNU. This is to strengthen the link between the industry and the PhD and MSc students at SFI CASA.

Furthermore, the Core Team has bi-weekly meetings, led by the Centre Director. A number of seminars and talks have been held online through 2021.

The Centre Board met online on 26 May and 10 November.

Above: From left Lars Edvard B. Dæhli, Magnus Langseth,and Tore Børvik. Left: Trond Auestad and Vegard Aune.
Below: From left Rene Kaufmann, Trond Auestad, and Bjørn Christian Abrahamsen. (Photos: Sølvi W. Normannsen and Vegard Aune).

Projectile IMPACT

One of the MSc projects in spring 2021 at SIMLab was «Projectile impact on plain and reinforced concrete slabs». Vetle Solheim Gjesdal and Øystein Eirik Kvist Jacobsen (photo) worked on determining how concrete plates behave under impact loading and validate existing computational methods. Concrete is frequently found in protective structures, especially when weight and space limitations are not present. This makes concrete of particular interest in fortification installations for defence purposes.

In January, the students cast concrete plates of 100 mm thickness and appurtenant material specimens in strength grade C75. After the specified weeks of curing, they impacted the slabs with projectiles to reveal their ballistic capacity. They performed the tests in SIMLab's ballistic range. Of particular interest was the effect of rebars on the perforation resistance. All component tests combine relevant material tests instrumented with Digital Image Correlation.

The material test data was used to calibrate proper concrete material models. Finally, the students carried out numerical simulations of the component tests using a finite element solver. The data generated will validate and verify some frequently used numerical methods involving impact loading of concrete structures. The project involves collaboration with CASA partner the Norwegian Defence Estates Agency (NDEA).

Pipelines put to TEST

Equinor and Gassco are collaborating with SFI CASA on testing full scale sections of steel pipelines from the Johan Sverdrup field in the North Sea. The research team are investigating how the concrete coating on the pipe contributes to energy absorption during impact from a falling anchor or trawl gear. Pipelines that carry oil and gas along the ocean floor must endure significant stress. One recurring challenge is the impact of ship anchors or gear from fishing trawls. Such interference is a recurring problem in areas where petroleum and fishing industries overlap. Incidents like this could have severe consequences. Therefore, it is essential to warrant the ability of pipelines to withstand loads and thus ensure that they operate safely throughout their predicted lifetime.

The pipeline sections put to the test by CASA, energy company Equinor, and gas transporter Gassco are from the Johan Sverdrup oil field in the North Sea. The diameter is approximately 1 metre, including a 50-millimetre-thick concrete coating and a corrosion protection layer. The primary purpose of the coating is to provide the required submerged weight. Also, it serves to protect the steel pipeline against accidental loading. SFI CASA's partner Equinor has thousands of kilometres with pipelines crisscrossing the seabed in Norwegian and more distant waters. In the event of pipeline damage, the company needs simulations for damage assessment evaluation.

BLAST Events

During the past two decades, the threat of deliberate use of high explosives against civilian targets has resulted in a significant increase in research activity on blast-loaded structures. Amatul Baki Ayesha Binte Awn Syed and Ingrid Gisnås collaborated on their MSc thesis in spring. The thesis was entitled «Dynamic response of flexible structures subjected to blast loading». Blast events in urban environments introduce new materials, lightweight and flexible structures to the scope of protective design. Depending on the blast intensity and the structural properties, the dynamic response of the structure may undergo significant changes. A large variety of methods has been proposed to predict both the loading and structural response in these extreme loading situations. Therefore, it is necessary to review the capabilities of the current computational and design methods to predict the response of flexible structures subjected to blast loading. This is necessary for the development of safe and cost-effective protective structures. Associate professor Vegard Aune, Professor Magnus Langseth and Nicolas Neumann from SFI CASA´s partner Multiconsult supervised the students. Syed and Gisnås performed blast experiments on flexible beams. They used the data to evaluate the performance of some frequently used computational methods in blast-resistant design.

INTERNATIONAL COOPERATION AND LEADING-EDGE RESEARCH

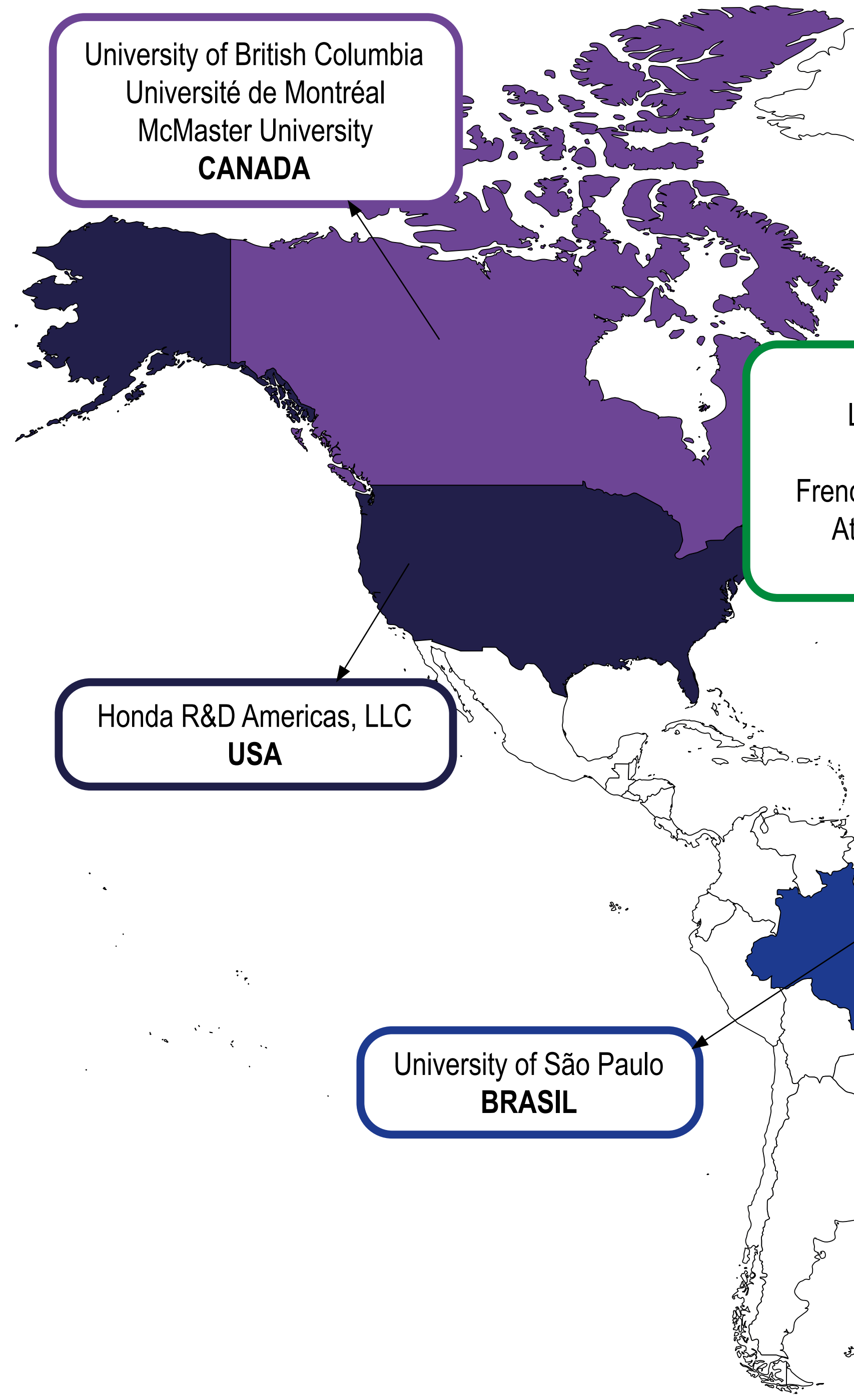
International cooperation is one of the success criteria for an SFI centre and SFI CASA has international collaboration in several ways. Among SFI CASA's partners there are four companies from outside Norway (Audi, BMW, Honda, and Renault). SFI CASA also has strong interaction with universities, companies and research organizations abroad.

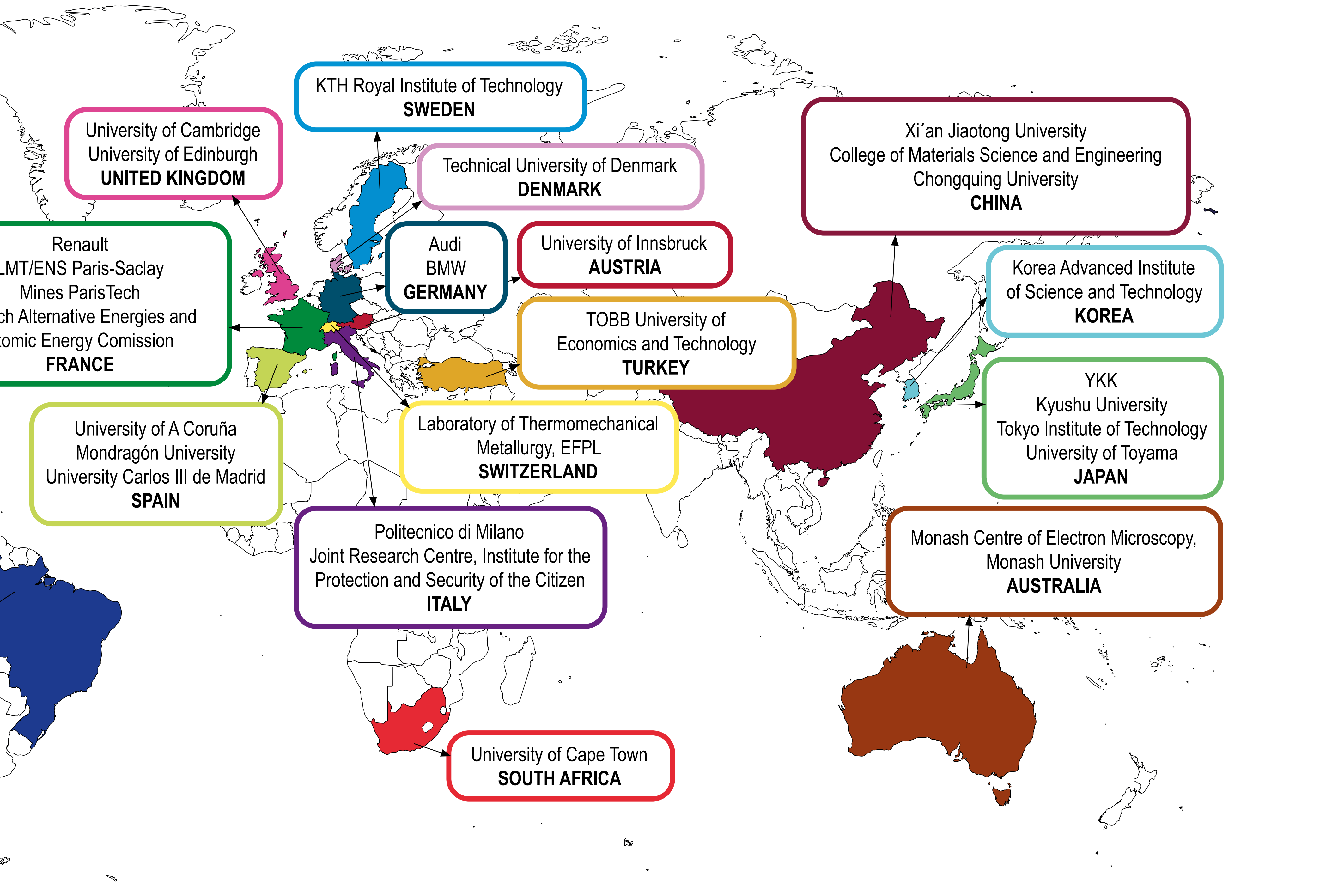
SFI CASA is a member of the European Automotive Research Partners Association, EARPA, an association of automotive R&D organizations. Four of the key researchers in SFI CASA are members of the DYMAT, a European association for the promotion of research into the dynamic behavior of materials and its applications. Professor Magnus Langseth has a seat in DYMAT's governing board.

The key researchers in SFI CASA all have an extensive international network. This is partly a result of the researcher's visibility in the academic environment through publications in peer-reviewed journals and presentations at international conferences. In addition, three of the Centre professors are editors in highly ranked international journals.

The cooperation with top international research groups ensures that the Centre transfers leading-edge technology to the partners and, at the same time, is able to define innovative research areas of importance to the partners.

SFI CASA aims at being world-leading. Reaching that goal requires advice from the best. A Scientific Advisory Board (SAB) of international experts has been appointed.

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Protection and Security of the Citizen
ITALY
Monash Centre of Electron Microscopy,
Monash University
AUSTRALIA
University of Cape Town
SOUTH AFRICA

SELECTED CONCURRENT PROJECT

Toppforsk Project FractAl:

Toppforsk funding is a targeted initiative for providing substantial, long-term support to research groups that have the potential to reach the top of their field internationally.

Recrystallised and fibrous grain structure, aluminium.

When launching the programme in 2016, the then Norwegian Prime Minister Erna Solberg pointed out that the project is a crucial step in cultivating more world-leading academic groups in Norway. Funding is allocated to projects that have received the highest score after review by panels of international referees.

The Toppforsk project FractAl started in August 2016 and lasts for five years. It is a concurrent project to SFI CASA, and the activities coordinate closely with the activities in the Centre.
The project deals with microstructure-based modelling of ductile fracture in aluminium alloys. In the design of aluminium structures against failure, the strength and ductility of the material are essential factors. To design lightweight structures, it is often necessary to use high strength aluminium alloys while taking advantage of ductility in full. For aluminium alloys, increased strength often comes at the expense of the ductility of the material. Thus the risk of structural failure may increase. Therefore, it is crucial to have good models for the ductility of aluminium alloys under different load situations.

In FractAl, a new microstructure-based modelling framework for ductile fracture in aluminium alloys is developed and validated. It involves modelling and simulation at multiple scales as well as customized laboratory experiments.

Besides building a basic understanding of ductile fracture in aluminium alloys, the modelling framework enables designers and engineers to select the most suitable aluminium alloy for a given structure with fewer time-consuming and costly mechanical tests than previously. The framework can also be used to tailor alloys with ideal strength and ductility for a given structure. This could pave the way for an entirely new way to design aluminium structures.
The results obtained in FractAl are implemented in the SIMLab Tool Box. They will thus be made available to the partners of CASA as well as for others in industry.
The core team of the project consists of Professors Odd Sture Hopperstad (principal investigator), Tore Børvik and Ole Runar Myhr at SIMLab, Department of Structural Engineering, NTNU.

SIMLab´s NEW Associate professor

By appointing Miguel Costas as an Associate professor, SIMLab strengthens its activities within the design and modelling of aluminium structures. An external grant from Hydro funds the position for the first five years. After that, NTNU takes over all obligations. Also, the university funds the salary of one PhD candidate for three years that is linked to the position.

Miguel Costas graduated with a Master of Science in Civil Engineering from the University of A Coruña in 2011. In January 2016, he earned his PhD with the thesis «Crashworthiness analysis and design optimisation of hybrid impact energy absorbers». The work awarded him the Cum Laude, international distinctions, and the extraordinary doctorate award. Costas´ research topics include computational and experimental solid mechanics, structural optimization, metal plasticity, crashworthiness, and ballistic penetration.

«Not only does this position strengthen our collaboration with Hydro. It will also contribute to extending our activities related to industrial implementation after the end of SFI CASA in 2023», Costas said when CASA shared the news about his position.

Also, he assumes that it will enable the group to explore new research fields within applied research. «I am happy to contribute to these challenging tasks», he says.

Miguel Costas, who had his first day in the new position on 1 July, is also a professional pianist. He graduated in 2005 from the Conservatory of Santiago de Compostela in Spain.

A Close Race in PARLIAMENT

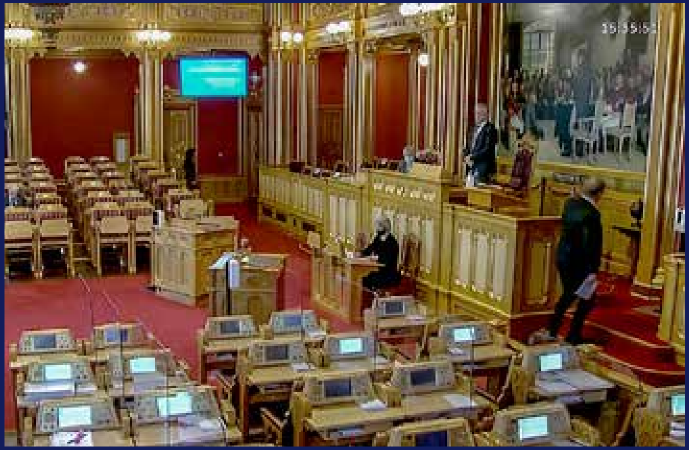
SFI CASA and SIMLab were part of the Norwegian Parliament's debate on societal security on 9 March. The majority in the Standing Committee on Justice put forward a proposal that said that «Parliament asks the government to initiate a national investment in expertise in securing potentially vulnerable buildings and structures. This investment should be in the form of a centre that can provide research, expertise, and continuing education for the public and private sectors».

During the debate, SIMLab, SFI CASA and NTNU received more than 3 minutes of support and praise from the country's top rostrum. Unfortunately, the member of Parliament Jorodd Asphjell (Labour Party) failed to get the governing parties to vote for the proposal.

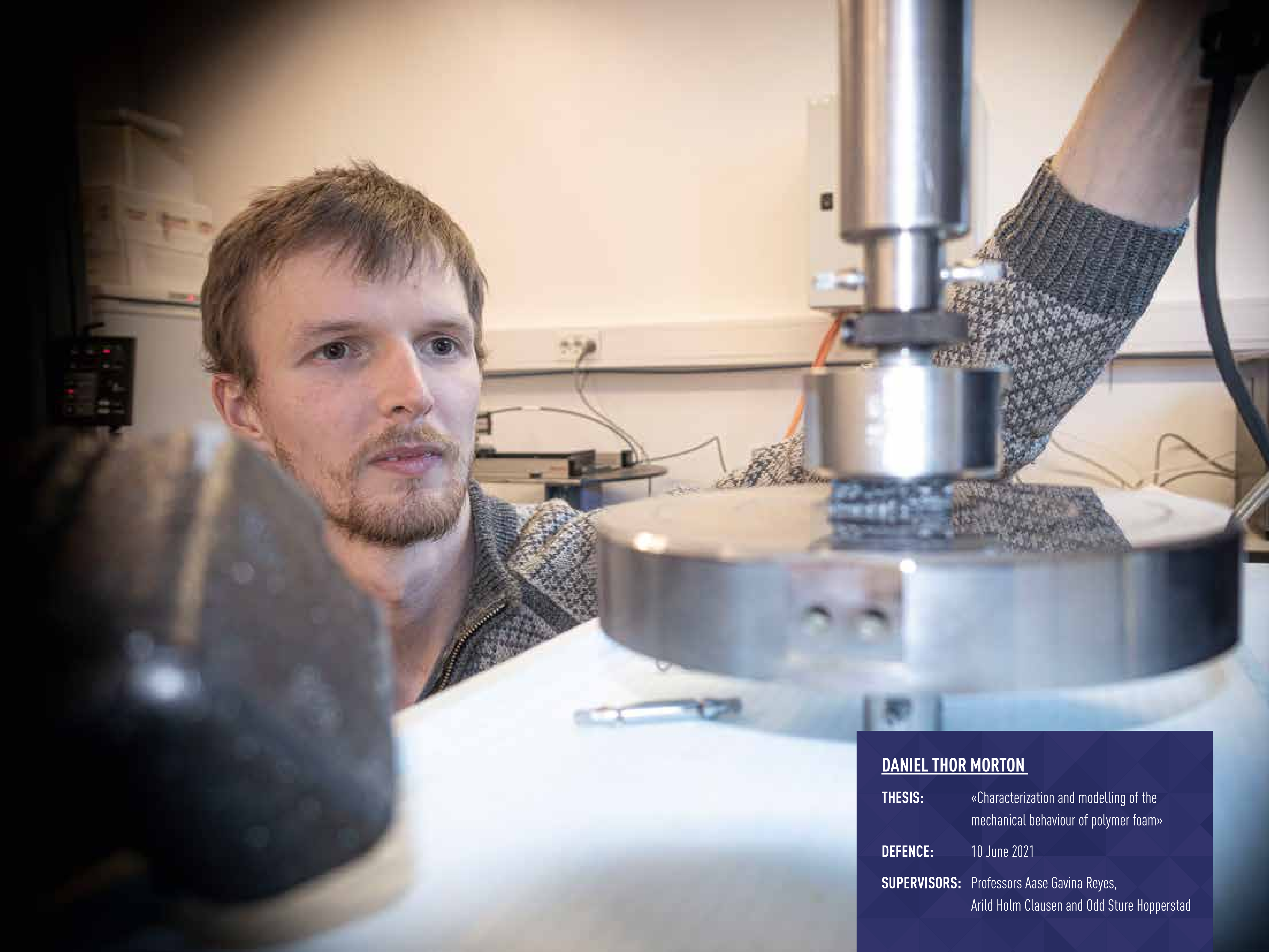
For SFI CASA director Magnus Langseth, the positive praise, and the close vote of 42 to 45 was inspiring.

For several years, he has put a lot of effort into the possibilities of establishing a new, national centre for research in physical security. The initiative proposed to the Norwegian authorities will help to educate more MSc and doctoral engineers who are trained to use the latest tools and have a holistic perspective on safety.

«The idea was defeated in Parliament this time. However, I am sure new opportunities will come soon», said the ever-optimistic Magnus Langseth after the Parliamentary debate.



Meet our new Doctors: Jianbin Xu and Daniel Thor Morton



DANIEL THOR MORTON

THESIS: «Characterization and modelling of the mechanical behaviour of polymer foam»

DEFENCE: 10 June 2021

SUPERVISORS: Professors Aase Gavina Reyes, Arild Holm Clausen and Odd Sture Hopperstad

Capturing the Behaviour of FOAMS

They are ultra-light, excellent energy absorbers, and they may save your life. This brilliant blend of properties made Daniel Thor Morton delve deep into the details of polymer foams.

Morton has investigated foams used in the bumpers of modern cars. He has worked on understanding and describing their response to impact under different loading rates, climatic conditions, and temperatures. The internal structures of the foams bear close resemblance to soapy foam. In his doctoral thesis, Morton presented a micromechanical model that resembles these structures and is used to model the behaviour of the foam.

HIGHLY ATTRACTIVE TO INDUSTRY

The purpose is to enable industry to design and develop components more efficiently by utilizing virtual models and engineering software. Daniel Morton says that the design process, and ultimately the product, will benefit from improvements in the efficiency and accuracy of such tools.

The combination of low weight and excellent energy absorption makes polymer foams highly attractive to industry. When applied in cars and bumpers, they provide pedestrian impact protection. You will also find them in personal protective equipment like helmets. Besides, they can be tailored for specific use in the packing industry, in electronics, aerospace, building construction and medical applications.

FOAMS UNDER COMPRESSION, TENSION, SHEAR

In the test facilities of SIMLab, Morton has subjected small cubic samples from bumper components to compression, tension, and shear. He also studied their behaviour under different temperatures and deformation rates. The idea is to capture as much response as possible to improve our understanding of responses in different climates and crash scenarios.

«Take, for instance, the effect of different temperatures. Ideally, a pedestrian impact case should yield similar results in northern Norway as in Spain. But this is difficult to predict without comprehensive understanding of the mechanical behaviour. Hopefully, my work will provide a more complete picture of foams subjected to complex deformation states», he says.

TAILORMADE AND DESIRABLE

The materials are challenging to describe with existing material models. The complexity comes from the internal geometry of the foams and the broad range of possible deformations. Foams are cellular materials. They can be tailored to specific applications by choosing an appropriate bulk material and manufacturing process. Desirable qualities include low density and good capability to absorb energy. Foams with polymer bulk material can be classified as either open or closed cells, depending on how the material is distributed within the microstructure.

LIKE SOAPY FOAM AND FLAT FACES

To give an idea of the challenges, we must delve into some of the technicalities of Morton´s work. Imagine the previously mentioned resemblance to soapy foam. Then, visualize that you step inside a closed-cell foam. Morton describes it as you would be surrounded by flat faces. Each edge connects two faces and each corner connects three faces. To get a rudimentary idea of the structure, you can imagine a hexagon in three dimensions.

«The wall of this structure would be composed of the base material, in our case, a polymer. The edges connecting the faces would be relatively thin. On the other hand, for an open foam you would see most of the material located along the edges, while the faces would be open».

THE MAIN BENEFITS OF FOAM

If the foam is subjected to compression, the thin walls and edges will start to deform and buckle, allowing the material to decrease volume without too much effort. According to Morton, this is the main benefit of foams compared to a solid material which does not easily change its volume.

«Irrespective of the material it is made from, most foams have this quality. However, the base material determines some of the other behaviour. For example, how much it springs back after being deformed».

A MODEL COMBINING A WIDE RANGE OF SETTINGS

Generally, micromechanical modelling is well developed and widely used, also on foam. The framework developed as part of Morton's research uses what he calls periodic boundary conditions. This allows the modelling of large deformations. Also, it accepts a wide range of settings, such as distributing material between the cell walls and cell corners. Most other models focus on one or both of these areas. Morton attempts to combine them, and when taking both into account, this model can provide an improved description of an actual foam.

A FOUNDATION FOR FURTHER RESEARCH

«Hopefully, my work will provide a comprehensive picture of the behaviour of foams when subjected to complex deformation states», he says.

Morton also hopes that his work has laid the foundation for further research and model development. He says it allows existing models to be evaluated so that we can choose the best currently available model.

«The information gained and our testing and modelling work will be a good starting point for others to better understand and capture the complex mechanical response of foam», he adds.

A BUMPY Ride

Have you ever tried to ride a bicycle smoothly on a dirt road full of cracks and potholes? According to Dr Jianbin Xu, it is comparable with trying to understand the Portevin-Le Chatelier effect on some metallic materials.

Jianbin Xu has spent 4 years at SFI CASA, investigating deformation behaviour of aluminium alloys. More precisely, he studied the mechanisms related to a phenomenon that has been well-known for almost 200 years: the Portevin-Le Chatelier (PLC) effect.

«The PLC effect has been extensively studied, and massive amounts of literature on it can be found. Ground-breaking research has not appeared for quite a long time. There is still a way to go to accurately predict the behaviour of a material. I just added some bricks to the wall that has already been built», says Xu, who defended his PhD thesis in June 2021.

RIDING SUPER FAST AND SUPER SLOW

The PLC effect is related to a strengthening mechanism, but it has a catch: The additional alloying element causes the alloy to deform in an unstable manner. This in turn, can lead to poor ductility and thus, premature failure. Ductility is a measure of the ability of a material to bend or stretch before it cracks or fails. Jianbin Xu compares the aluminium deformation with riding a bicycle on a dirt road. «If you ride the bicycle super-fast like a Ferrari, you will not feel the bumps at all», he says. The same thing happens if you cycle as slowly as possible and avoid the bumps by paying full attention to the road. These two options are also valid for the deformation of aluminium: «If the metal deforms at a really high strain rate or a low strain rate the PLC effect will disappear». The third option, is to ride at normal speed, feel all the bumps and face a high risk of crashing your bicycle. To continue the comparison: Strong instability and dislocations might occur more often for the most used aluminium alloys. ¨We want to understand this process. And maybe one day we will be able to understand the phenomenon and the problem of the Portevin-Le Chatelier effect ¨, says Jianbin Xu.

A FUTURE GUIDE FOR THE DESIGN OF ALLOYS

Scientists talk about the PLC effect as «a serrated stress-strain curve that exhibits inhomogeneous deformation in the material». When illustrated, it looks like the profile of a saw blade. For producers of alloys containing magnesium, it is a constant headache. The PLC effect is known to induce blue brittleness in steel. The loss of elasticity may cause rough surfaces to develop during deformation. Thus, the material renders results that are useless for car-body components, sheet-forming applications, or other casting parts.

«The work I have done may serve as a guide for the design of alloys, or for quality control in the automotive industry», says Xu.

UNDERSTANDING THE DEFORMATION MECHANISM

He holds up a dog bone-shaped sample of aluminium. The sample origins from a 5xxx series aluminium alloy, extensively used in the beverage packaging and automotive industry.

«Undesirable surface finish and discontinuous thinning during sheet metal forming have caused challenges for these applications», Xu explains.

The forming process of alloys often has temperature variation. The strain rate also changes with time and from one location to another in a forming operation. Therefore, simulation of forming processes and related tests needs constitutive descriptions accounting for variations in temperature and strain rate.

«The idea of understanding the deformation mechanism at a deep-level triggers me», says Xu, who has been a part of the Lower Scale programme at SFI CASA.

CONNECTING LOWER AND CONTINUUM SCALES

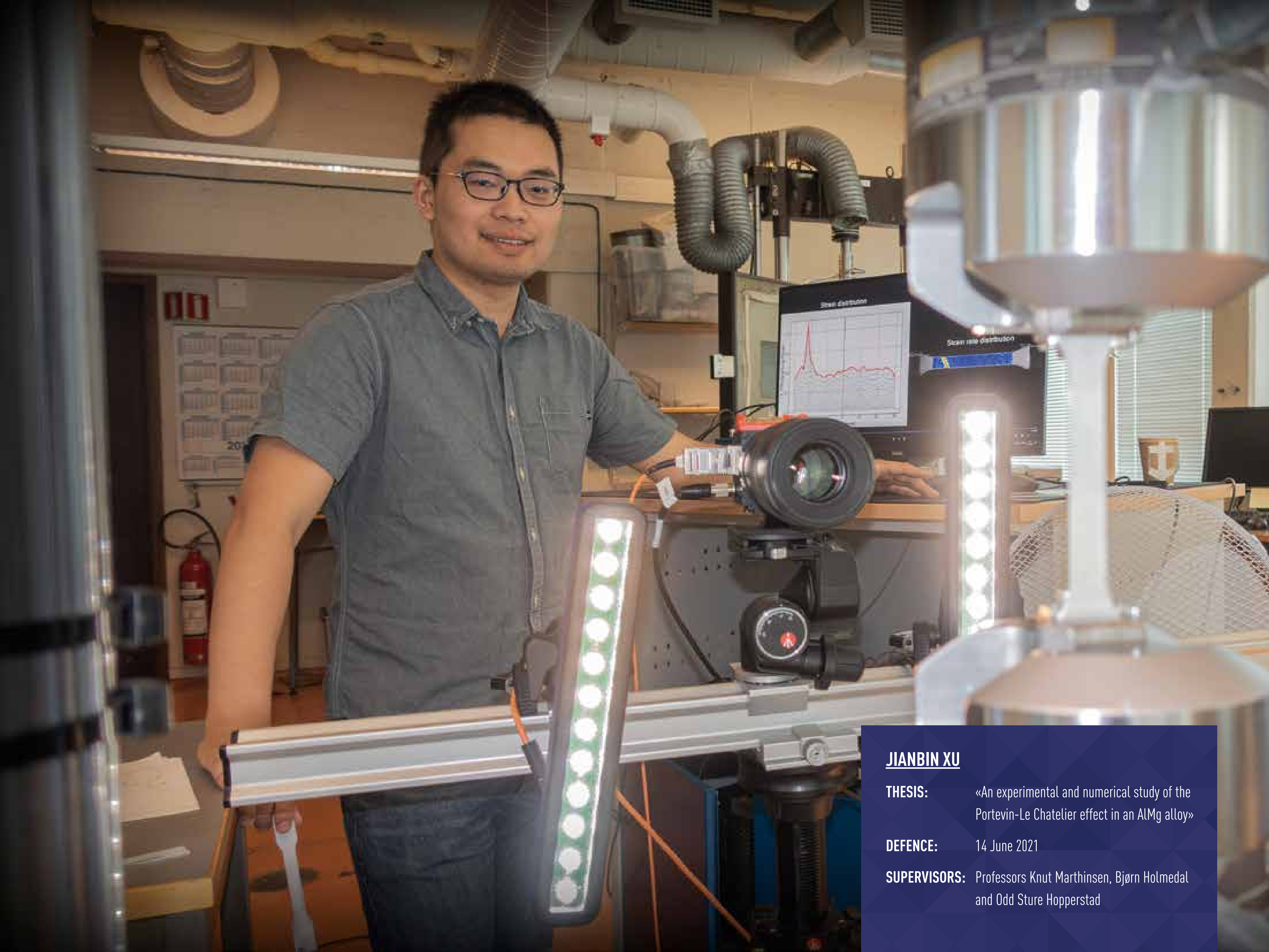
He had three objectives listed for his work. First, he studied the influence of temperature and strain rate on the PLC band nucleation and propagation. This was done by both experiments and material modelling. Second, implementation and validation of a physics-based model were applied to capture the mechanical behaviour of the material. According to Xu, this work provided excellent agreement with the experimental results. The long-standing unsolved jerky flow scenario issue brought by the variation of temperatures and strain rates, is solved. The third task was the Finite element modelling of the band formation, propagation and band morphology.

SIMULATIONS AND EXPERIMENTS AGREE QUITE WELL

«A finite element model was implemented to accurately simulate the subtle features of PLC bands. The simulations and experiments agreed quite well», he says.

Xu declares that he has spent 4 years of challenging and enjoyable work at SFI CASA. He comes from Yancheng, a small city in eastern China. He jokes that he is still surprised by the choice he made several years ago, about coming all the way to Norway. As an undergraduate, he studied magnesium alloys, which is another light metal. When an opportunity arose at NTNU in Trondheim he decided to go.

From January 2022 he will work as a post doc at SFI CASA.



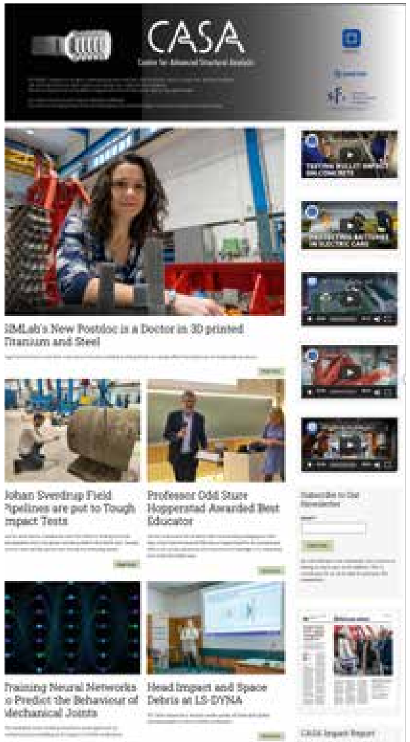
JIANBIN XU

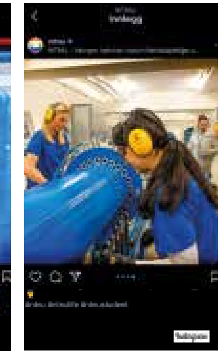
THESIS: «An experimental and numerical study of the Portevin-Le Chatelier effect in an AlMg alloy»

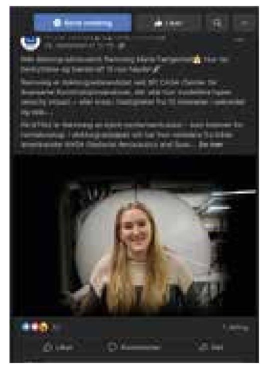
DEFENCE: 14 June 2021

SUPERVISORS: Professors Knut Marthinsen, Bjørn Holmedal and Odd Sture Hopperstad

VISIBILITY







Media strategy

SFI CASA has a media strategy for popular scientific presentations of our research. We aim to contribute to a knowledge-based, open public debate. In 2021, we continued to make female researchers and profiles particularly visible. We put an effort in recruiting more females and thus contribute to a more even gender balance in our research field.

Website

The essential tool to make SFI CASA visible is the website sfi-casa.no. The site works as a platform for sharing and spreading content in social and mainstream media. We publish research news, feature stories, videos and in-depth interviews with key personnel working with or connected to the Centre. We published a total of 36 posts on sfi-casa.no in 2021. The content was distributed in 10 newsletters to partners, contacts, and other subscribers in our social and professional network.

CASA has introduced a Technical Newsletter (TN) intended solely for the partners in the Centre. This year, we distributed 4 TNs, down from 9 in 2020.

Social media

We have excellent collaboration with the communication divisions in the NTNU administration and the Faculty of Engineering. We share content posted on our website via NTNU News, Norwegian SciTech News/Gemini, YouTube, Instagram, Twitter, and the Facebook page NTNU Science and Technology and Twitter.

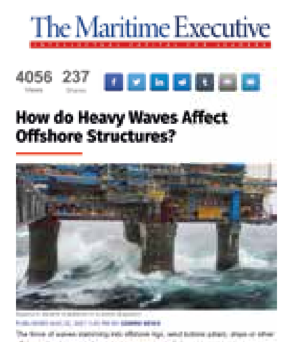
CASA in the Media

CASA had its share of publicity in 2021, despite the extraordinary circumstances around Covid-19.

Early January, the local newspaper RanaBlad published a 2-page story on SFI CASA´s Post doctor Sindre Olufsen. As he works from Campus Helgeland in Mo i Rana, CASA has got its first-ever satellite office.

Later that month, The Standing Committee on Justice hosted a Parliamentary hearing regarding the Government's new white paper on societal security. Professor Magnus Langseth shared his views in the hearing. The same day, on 19 January, Professors Langseth and Børvik published a chronicle on the challenges in the white paper in the Norwegian newspaper Adresseavisen.

In March, the magazine Forskerforum brought a story on possible research fraud. They interviewed associate professor Vegard Aune, who suddenly had found himself co-author of an article he had never heard of.



In May, we had a prominent visitor. Henrik Asheim, the Minister of Research and Higher Education, had invited himself to meet staff at SFI CASA to learn more about research-based innovation. According to the NTNU University Paper, the Minister was impressed and described the virtual event as inspiring.

Before the summer holidays, we presented the SLADE KPN project in a story that would become the most widely shared and spread in 2021. SLADE is a Knowledge-building Project for Industry (KPN) involving researchers from SINTEF Ocean and NTNU. Several people from SIMLab/CASA collaborate on the project´s overall goal: to increase safety at sea. The article´s title was «Measuring the impact of extreme waves on offshore structures». It was published in NTNU and SINTEF´s joint research magazine Gemini and the English edition of SciTech News. During the autumn, the story was picked up by Teknisk Ukeblad, and international publications like Journal of Petroleum Technology, The Maritime Executive, Engineers Online, Ocean News & Technology and others.

In November, Professor Odd Sture Hopperstad received The Norconsult Award for the best educator at Civil and Environmental Engineering at NTNU. Hopperstad´s students honoured him for his exceptional efforts to convey advanced and theoretical knowledge in a rewarding and understandable way. The magazine Bygg Fakta brought the story.

Invited and guest lectures

- Randi Holmestad. Crash course in TEM (with examples from microstructure and precipitates in Al alloys). Global Engineering Lectures, Toyama University; 28 September 2021 (Online).
- Randi Holmestad.TEM used to study microstructure and precipitates for understanding 6xxx alloys. Global Engineering Lectures, Toyama University; 28 September 2021 (Online).
- Randi Holmestad. Deformed Al-Mg-Si alloys studied at the nanoscale. MRM2021- Materials Research Meeting, 15 December 2021 (Online).
- Randi Holmestad. Nanoscale characterisation of deformed Al-Mg-Si alloys. Thermec 2021 Virtual conference

Lab visits at CASA

- A group of three members of Parliament visited CASA's laboratories on 1 September.
- Seven representatives from the Ministry of Transport paid a visit on 8 November.

PhD defences in 2021

- 9-10 June, Daniel Morton, Characterization and modeling of the mechanical behavior of polymer foam
- 14 June, Jianbin Xu, An experimental and numerical study of the Portevin-Le Chatelier effect in an AlMg alloy

Research visits at SFI CASA

- PhD student Ramón del Cuvillo Mezquita from the Universidad Carlos III de Madrid, Spain, visited CASA in the period October-December.

Concurrent projects

KPN SLADE (2019-2021)

KPN project SLADE on fundamental investigations of violent wave actions and impact response. The objective of the SLADE project is to improve safety at sea, for which impact loads from steep and energetic waves represent a critical part of the structural design. This requires a better understanding of the mutual interaction between the impacting wave and the response of the structure. Associate professor Vegard Aune supervises one post doc at the SIMLab research group.

INTPART (2019-2023)

Norwegian-Japanese Aluminium Alloy Research and Education Collaboration: The objective of this INTPART project is to develop world leading education and research in the aluminium field in collaboration between NTNU, University of Toyama, Tokyo Institute of Technology, Kyushu University, SINTEF, Hydro and Japanese aluminium industry.

ALLDESIGN (2018-2022)

Rational Alloy Design is a NTNU project on digital materials design of aluminium-based alloys. Professors David Morin, Randi Holmestad, and Knut Marthinsen supervise one PhD candidate each in the ALLDESIGN project.

FractAl (2016-2022)

Microstructure based modelling of ductile fracture in aluminium alloys, FractAl. This FRIPRO Toppforsk project is run by professors Odd Sture Hopperstad, Tore Børvik and Ole Runar Myhr from NTNU's Structural Impact Laboratory along with partners Ahmed Benallal LMT/ENS Paris-Saclay, France and Jonas Faleskog from KTH Royal Institute of Technology in Sweden. The FractAl project employs one researcher, two post docs and four PhD candidates.

Education and Research Grant (2018-2022)

The Norwegian Ministry of Justice and Public Security funds a professorship for Vegard Aune on physical security at the SIMLab research group. NTNU funds one PhD candidate in connection to the professorship. The overall goal of the project is to strengthen education and research in Norway on civil engineering structures and critical infrastructure prone to extreme loading events.

KPN SumAl (2019-2024)

Solute cluster manipulation for optimized properties in Al-Mg-Si based Al alloys. Professors Randi Holmestad and Knut Marthinsen are involved in this KPN project, working with the understanding of early-stage clustering and ordering of solute atoms in aluminium alloys. SFI CASA partners Benteler, Hydro and SINTEF are also involved in the project.

IPN STIP (2020-2023)

The goal of the project is to develop methodology to accurately evaluate the capacity of flexible pipes with a polyvinylidene difluoride (PVDF) pressure liner. The project is run by Enodo AS and employs one post doc at the SIMLab research group.

KPN Expect (2021-2024)

This project is lead by Benteler Automotive Raufoss and addresses the rapidly growing market for battery tray protection systems for electric mobility and the BEV (Battery Electric Vehicle) market. The project employs one post doc working on ductility of complex profiles for crash management performance, and simulation and optimization of crashworthiness of extruded aluminum profiles.

SFI PhysMet (2020-2028)

The Centre for Sustainable and Competitive Metallurgical and Manufacturing Industry is hosted by the Department of Materials Science and Engineering at NTNU. CASA professor Knut Marthinsen is the Centre Director.

Awards

Professor Knut Marthinsen received THERMEC'2021 Distinguished award in recognition of his contribution in the field of materials science.

Professor Odd Sture Hopperstad received the Norconsult award for best educator at Civil and Environmental Engineering at NTNU.

1st row from left: Benjamin Stavnar Elveli, Andria Antoniou, Kamila Zablocka, Håvard Næss, Rannveig Marie Færgestad. 2nd row from left: Rene Kaufmann, Sigurd Aune, Sølvi Waterloo Normannsen, Tore Børvik, Knut Marthinsen, Stéphane Dumoulin, Térence Coudert, Virgile Delhaye, Peter Karlsaune, 3rd row from left: David Morin, Ruben Løland Sælen, Øystein Eirik Kvist Jacobsen, Jonas Rudshaug, Vetle Espeseth, Karoline Osnes, Anne-Sophie Sur, Magnus Langseth, Susanne Thomesen, Lars Edvard Blystad Dæhli, Vegard Aune, Martin Kristoffersen, Odd Sture Hopperstad. Row 4: Tore Wisth, Victor André, Miguel Costas, Einar Schwenke, Jonas Hund, John Fredrick Berntsen, Torodd Berstad, Marcos Fernandez, Randi Holmestad, Bjørn Håkon Frodal. (Photo: Ole Martin Wold)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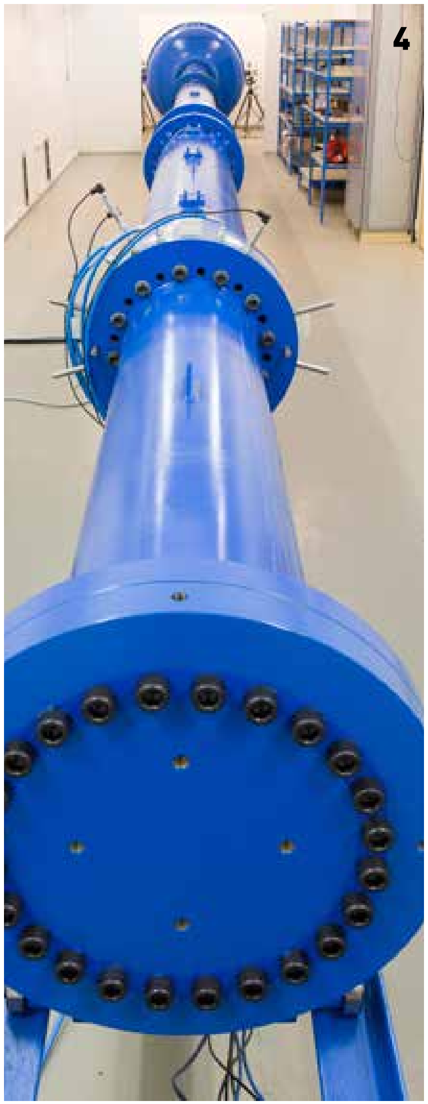
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SFI CASA has access to test facilities in several laboratories at NTNU and SINTEF. Here is a list of the most important testing equipment.

Gas gun (1)

This is a compressed gas gun for ballistic impact studies. A variety of projectile geometries can be fired with a maximum velocity of 1000 m/s.

Self-piercing riveting machine (2)

In this machine self-piercing riveting can be carried out of sheets under industrial conditions.

Droptower impact system (3)

In this machine impact testing of materials and small components can be done at high and low temperatures. The mass of the projectile ranges from 2-70 kg and gives an impact velocity in the range 0.8-24 m/s. All tests can be carried out with an instrumented nose which gives the impact force as a function of time.

SIMLab Shock tube facility (SSTF) (4)

The tube is 18.2 m long and is divided into six sections and ends in a 5.1 m^3 dump tank. The tube starts with a circular internal cross-section with a diameter of 0.34 m before it is transformed to a square cross-section of 0.3 m x 0.3 m. Threaded holes in the tube floor enable test specimens to be mounted in the test section. Windows in the test section and the dump tank allow high-speed cameras to capture the structural response during an experiment. In 2018 the SSTF was extended with a glass channel module. This channel gives increased insight into fluid-structure interaction effects during testing of energy absorbing components. The glass channel is 0.6 m long and enables flow visualization and a reaction wall equipped with load cells.

Split-Hopkinson pressure bar (SHPB) (5)

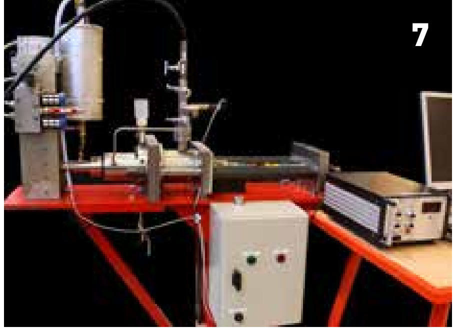
The split-Hopkinson pressure bar consists of a high-pressure chamber unit that can accelerate a striker bar against the end of the input bar. A compression stress wave is then generated in the input bar and the test sample sandwiched between the input and output bars is subjected to dynamic loading.

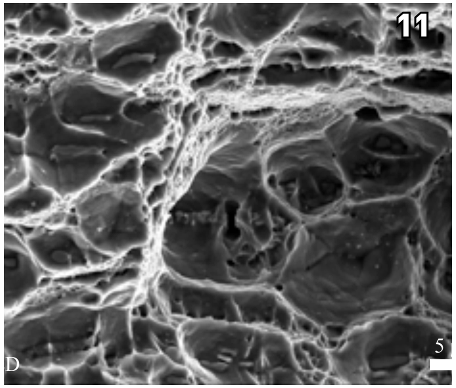
Stretch bending rig (6)

The stretch-bending rig applies a combined bending and axial tensile/compressive loading to the test component. The length of the specimens is 1-2 m, and they are bent around an exchangeable die with a defined curvature. The rig has been employed in tests where the bending operation of car bumpers is studied. It has also been used to study the behaviour of pipelines subjected to impact and subsequent stretching.

Hydro-pneumatic machine (HPM) (7)

The hydro-pneumatic machine (HPM) is a device for tensile material testing. It operates in the strain–rate range between 1 and 100 s^{-1}.





Pendulum impactor (Kicking Machine) (8)

The pendulum accelerator is a device for impact testing of components and structures. The test rig accelerates a trolley on rails towards a test specimen fixed to a reaction wall. The accelerating system consists of an arm connected to a hydraulic/pneumatic actuator system. The maximum energy delivered to the trolley is approximately 500 kJ. At present the mass of the trolley is between 400 and 1500 kg, giving a maximum velocity between 35 m/s and 26 m/s.

Split-Hopkinson tension bar (SHTB) (9)

The split-Hopkinson tension bar is a device for material testing at strain rates in the range between 100 and 1500 s^{-1}. Data is recorded with strain gauges and high-speed cameras. A plexiglass chamber facilitates tests at low and elevated temperatures.

Cameras (10)

Impact testing of materials and structures are recorded using high-speed cameras. The Kirana-05M camera has a maximum frame rate of 5 000 000 per second (FPS) allowing detailed studies of crack propagation. In addition, the research group has four more high-speed cameras and several cameras for Digital Image Correlation measurements.

Scanning electron microscope (SEM) laboratory (11)

SFI CASA has access to a SEM lab with the following equipment: Zeiss SUPRA 55VP (LVFESEM, 2006), Hitachi S-4300SE (FESEM, 2002), Zeiss, Ultra 55LE, FESEM (2007), Jeol 840 (1989).
Three SEMs are equipped with EDS and EBSD. The laboratory has in situ sub-stage systems for EBSD tensile and thermo-mechanical experiments (heating and cooling down to -60 °C).

Transmission electron microscope (TEM) laboratory (12)

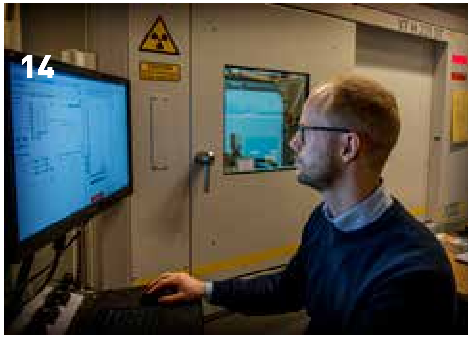
SFI CASA cooperates with the TEM Gemini Centre at NTNU, providing SFI CASA access to five TEMs: a JEOL double corrected ColdFEG ARM200F (2013), a JEOL 2100F (2013), a JEOL 2100 (2013), a Philips CM30 (1989) and a JEOL 2010 (1993). The TEM Gemini Centre also has a well-equipped sample preparation lab and computing facilities. NORTEM II (project leader Randi Holmestad) got support from the INFRA program in the Research Council, so Department of Physics will during the next years get a new top level transmission electron microscope. The laboratory includes a Merlin direct electron detector for electron diffraction experiments. The MDED allows cutting edge diffraction experiments for advanced and accurate defect analysis, phase mapping, magnetic and electrical field mapping, and orientation mapping at very high spatial resolution (nanometer scale) or with very high frame rates (21000 FPS).

Sheet metal forming machine (BUP) (13)

This multi-purpose hydraulic sheet metal forming machine is designed to test the formability of sheet metals. The machine has a 600 kN load capacity, a maximum clamping force of 50 kN, a maximum test stroke of 120 mm and a maximum test speed of 750 mm/min.

Computer tomography (CT) scanner (14)

The internal structure of materials and components can be studied in a non-destructive manner by X-ray computed tomography. The Nikon XT H 225 ST µ-CT scanner is capable of resolving structures with a size down to ten micro-metres revealing the otherwise hidden 3D-microstructure of specimens and materials. A Deben CT5000 tensile test apparatus allows for in situ imaging of samples subjected to tensile and compressive loading.



Photos:
1,2,6,7,9 13: Melinda Gaal
3,4,5,8,12: Ole Morten Melgård
10, 14: Sølvi W. Normannsen
11: Bjørn Håkon Frodal

PERSONNEL

PhD candidates and post docs

PHD CANDIDATES AND POST DOCS WITH FUNDING FROM SFI CASA							
Name	**Topic**	**Position**	**Start**	**Planned exam/end**	**Programme**	**Nationality**	**Gender**
Daniel Morton**	Modelling of the mechanical behaviour of polymer foams	PhD	2016	Defended in 2021	Polymeric Materials	Norwegian	M
Jianbin Xu**	Work hardening and Portevin-Le Chatelier (PLC) effect	PhD	2016	Defended in 2021	Lower Scale	Chinese	M
Kristoffer Aune Brekken**	Modelling and Optimization of Sacrificial Claddings	PhD	2017	2022	Structures	Norwegian	M
Einar Schwenke**	Modelling of viscoelasticity in Polymers	PhD	2018	2022	Polymeric Materials	Norwegian	M
Benjamin Stavnar Elveli**	Behaviour and modelling of steel plates subjected to combined blast and impact loading	PhD	2018	2022	Structures	Norwegian	M
Marcos Fernandez**	Modelling of aluminium components under large deformations	PhD	2018	2022	Structural Joints	Spanish	M
Victor André*	Modelling of multilayered joints	PhD	2019	2022	Structural Joints	German	M
Ruben Løland Sælen**	Modelling of polymers	PhD	2019	2023	Polymeric Materials	Norwegian	M
Jonas Rudshaug*	Modelling of glass	PhD	2019	2023	Structures	Norwegian	M
Sigurd Aune*	Modelling of welded aluminium joints	PhD	2020	2024	Structural Joints	Norwegian	M
Håvard Næss*	Machine learning in material mechanics	PhD	2021	2025	Metallic Materials	Norwegian	M
Rannveig Marie Færgestad*	Modelling and simulation of hypervelocity impact against debris shields for spacecraft protection	PhD	2021	2025	Structures	Norwegian	F
Øystein Eirik Kvist Jacobsen*	Modelling of concrete at extreme loading	PhD	2021	2025	Structures	Norwegian	M
Fanny Dameme**	Dynamic loading and ageing of adhesives	PhD	2021	2024	Structural Joints	French	F
Susanne Thomesen*	Cast aluminium	Post doc	2019	2021	Metallic Materials	Norwegian	F
Karoline Osnes*	Behaviour and modelling of glass	Post doc	2019	2021	Structures	Norwegian	F
Emil Christiansen*	Nanoscale characterization of aluminium	Post doc	2019	2021	Lower Scale	Norwegian	M
Andria Antoniou*	Blast loading	Post doc	2020	2023	Structures	Cypriot	F
Sindre Olufsen*	Modelling of ductile failure in polymers	Post doc	2020	2023	Polymeric Materials	Norwegian	M
John Fredrick Berntsen*	Industrial implementation	Post doc	2020	2023	Structural Joints	Norwegian	M

**Salary and operational costs from the Centre.*
***Operational costs from the Centre. Salary from other sources.*

1st row from left: Lars Edvard Blystad Dæhli, Susanne Thomesen, Rannveig Marie Færgestad, Martin Kristoffersen, Sigurd Aune, Benjamin Stavnar Elveli, 2nd row from left: John Fredrick Berntsen, Marcos Fernandez, Karoline Osnes, Rene Kaufmann, Håvard Næss, Anne-Sophie Sur. 3rd row from left: Bjørn Håkon Frodal, Einar Schwenke, Jonas Hund, Andria Antoniou, Øystein Eirik Kvist Jacobsen, Vetle Espeseth, Jonas Rudshaug, Ruben Løland Sælen, Victor André. (Photo: Ole Martin Wold).

Above: Post doc Kinga Somlo (left) and MSc student Tameem Karim Pathan. Below: MSc students presenting their projects autumn 2021 (Photos: Sølvi W. Normannsen).

New Associate professor II

By the end of 2021, SFI CASA's glass pioneer Karoline Osnes took up a new position as a structural engineer at partner Multiconsult. Fortunately, the collaboration continues, as Osnes has been appointed Associate professor II.

Dr Osnes knows more than most of us about how glass behaves under extreme loadings. During her post doc, she worked on collaboration projects with the Centre's industrial partners, mainly BMW.

«As an Associate Professor II, I can continue to follow and contribute to the research on glass. I can also guide users of the glass models that I developed during my PhD and post doc. Hopefully, I can also work to improve these models», Osnes states.

In addition, she will give lectures in Impact Mechanics on glass modelling.

PhD candidate Jonas Rudshaug's work is closely related to Karoline Osnes's field. Rudshaug has initiated a collaboration with Professor Dag Werner Breiby and his PhD candidate Kim Robert Bjørk Tekseth at the Department of Physics on finding and characterizing the microscopical surface flaws used as input in glass models. The collaboration is starting to bear fruit.

Rudshaug also has a collaboration project with BMW. During spring 2022, a new MSc student works on testing and modelling the windshields of cars provided by BMW.

PHD CANDIDATES AND POST DOCS ON CONCURRENT PROJECTS. THE TOPICS ARE HIGHLY RELEVANT FOR SFI CASA							
Name	**Topic**	**Position**	**Start**	**Planned exam/end**	**Programme**	**Nationality**	**Gender**
Asle Joachim Tomstad	Quasi-static and dynamic ductile fracture of aluminium alloys under low triaxiality	PhD	2017	2022	FractAl	Norwegian	M
Kristin Qvale	Microstructure-based modelling and simulation of ductile fracture in aluminium alloys	PhD	2018	2022	FractAl	Norwegian	F
Vetle Espeseth	Microstructure-based modelling and simulations of plasticity and fracture in aluminium alloys	PhD	2018	2022	FractAl	Norwegian	M
Anne-Sophie Sur	Running ductile fracture in pressurised steel pipelines	PhD	2020	2023	FME NCCS	German	F
Lars Edvard Dæhli	Micromechanical modelling of ductile failure in aluminium alloys	Post doc	2017	2022	FractAl	Norwegian	M
Bjørn Håkon Frodal	Modelling of aluminium	Post doc	2019	2022	FractAl	Norwegian	M
Rene Kaufmann	Impact response	Post doc	2019	2021	SLADE	German	M
Kinga Somlo	Simulation and optimization of crashworthiness of extruded aluminum profiles	Post doc	2021	2023	KPN Expect	Hungarian	F
Jonas Hund	Structural Integrity of PVDF pressure liners	Post doc	2021	2023	IPN STIP	German	M

Recruitment

Four new PhD candidates and two new Post docs started at SFI CASA in 2021. Former MSc students Håvard Næss, Rannveig Marie Færgestad, and Øystein Eirik Kvist Jacobsen started as PhD students in August. In addition, Fanny Dameme has been employed by Renault as an affiliated PhD student co-supervised by David Morin at SFI CASA. Two Post docs, Jonas Hund and Kinga Somlo, were employed as Post docs on two concurrent projects.

Due to coronavirus restrictions, only one PhD candidate visited the Centre in 2021.

MSc students
The following MSc students were associated with the Centre in 2021

Name	Sex M/F	Topic
Håvard Næss	M	Plated offshore structures exposed to violent wave impact
Rannveig Marie Færgestad	F	Modelling and simulation of hypervelocity impact against debris shields for spacecraft protection
Even Garshol	M	Modelling of steel plates subjected to impact and blast loading
Vegard Skauge Hjelmeland	M	Fluid structure interaction effects during the dynamic response of blast-loaded plates
Sigurd Vattekar Sandvoll	M	Design and modelling of vehicle security barriers
Ola Fjelltun Stensvand	M	Design and modelling of vehicle security barriers
Amatul Syed	F	Dynamic response of flexible structures subjected to blast loading
Ingrid Gisnås	F	Dynamic response of flexible structures subjected to blast loading
Vetle Solheim Gjesdal	M	Projectile impact on plain and reinforced concrete slabs
Øystein Eirik Kvist Jacobsen	M	Projectile impact on plain and reinforced concrete slabs
Kamila Zablocka	F	Additive manufactured protective structures
Olav Nordvik	M	Machine learning in material mechanics
Tameem Karim Pathan	M	Optimization of extruded aluminium profiles for battery protection in electric cars
Oskar Homme Misund	M	Additive manufactured protective structures
Kristoffer Frøyd Eriksen	M	Modelling of ductile fracture in steel structures
Eirik Hegre	M	Modelling of Joints in Large-Scale Analyses of Steel Structures
Hjalmar Emil Moter Hauge	M	Modelling of Joints in Large-Scale Analyses of Steel Structures
Ådne Skretting	M	Fatigue assessment of a generic steel bridge
Mari Solheim	F	Fatigue assessment of a generic steel bridge

On a SPACE Mission

Accurate and reliable modelling of debris impacts at hypervelocity is crucial to ensure safety and sustainability in space. Rannveig Marie Færgestad started her PhD position in August. Her aim is to improve and develop numerical methods and models of hypervelocity impact. Her research is valuable for designing and developing shielding for space stations, satellites, and crew capsules.

The growing orbital debris environment poses a significant threat to space missions. Micro-meteoroids or fragments from colliding satellites are transformed into millions of flying projectiles, and they travel at breakneck speed. Impacts can lead to anything from the gradual weakening of the protective shields of spacecraft to catastrophic collisions. Space technology is not one of CASA's core activities. However, the methodology is generic, and the research here focuses on improved physical protection against extreme impact. Thus, for Færgestad the Centre is perfect for conducting her research.

«Hypervelocity impact experiments are expensive and require specialized equipment. In laboratory settings, we cannot reach all relevant impactor mass and velocity combinations. This makes numerical simulations essential when designing debris shields. Every kg launched into space is expensive, so creating a design that minimizes weight and volume while ensuring the safety of the mission is vital», Rannveig Marie Færgestad says.

The following lists journal articles, conference contributions and other publications published in 2021.

Journal articles 2021

1. V. Aune, G. Valsamos, F. Casadei, M. Langseth, T. Børvik. Fluid-structure interaction effects during the dynamic response of clamped thin steel plates exposed to blast loading. International Journal of Mechanical Sciences 2021, Volume 195.(106263)
2. S. Bergo, D. Morin, O.S. Hopperstad. Numerical implementation of a non-local GTN model for explicit FE simulation of ductile damage and fracture. International Journal of Solids and Structures 2021, Volume 219 - 220.pp. 134-150.
3. M. Costas, M. Edwards-Mowforth, M. Kristoffersen, F. Teixeira-Dias, V. Brøtan, C.O. Paulsen, T. Børvik. Ballistic impact resistance of additive manufactured high-strength maraging steel: An experimental study. International Journal of Protective Structures 2021
4. M. Costas, D. Morin, J.K. Sønstabø, M. Langseth. On the effect of pilot holes on the mechanical behaviour of flow-drill screw joints. Experimental tests and mesoscale numerical simulations. Journal of Materials Processing Technology 2021, Volume 294.
5. P.H. Holmström, A.H. Clausen, T. Berstad, D. Morin, O.S. Hopperstad. A pragmatic orthotropic elasticity-based damage model with spatially distributed properties applied to short glass-fibre reinforced polymers. International Journal of Solids and Structures 2021, Volume 230-231.
6. H. Johannessen, O.H. Johannessen, M. Costas, A.H. Clausen, J.K. Sønstabø. Experimental and numerical study of notched SHS made of different S355 steels. Journal of Constructional Steel Research 2021, Volume 182.
7. M. Kristoffersen, K.O. Hauge, A. Minoretti, T. Børvik, Tore. Experimental and numerical studies of tubular concrete structures subjected to blast loading. Engineering Structures 2021, Volume 233, 1-21
8. M. Kristoffersen, O.L. Toreskås, S. Dey, T. Børvik, Tore. Ballistic perforation resistance of thin concrete slabs impacted by ogive-nose steel projectiles. International Journal of Impact Engineering 2021, volume 156
9. M. Mokhtari, W. Nam, J. Amdahl. Thermal analysis of marine structural steel EH36 subject to non-spreading cryogenic spills. Part II: finite element analysis. Ships and Offshore Structures 2021
10. W. Nam, M. Mokhtari, J. Amdahl. Thermal analysis of marine structural steel EH36 subject to non-spreading cryogenic spills. Part I: experimental study. Ships and Offshore Structures 2021 pp 1-9
11. S.N. Olufsen, P. Nygård, C. Ines Teixeira Pais, G. Perillo, O.S. Hopperstad, A.H. Clausen. Influence of loading conditions on the tensile response of degraded polyamide 11. Polymer 2021, Volume 229.
12. K. Osnes, J.K. Holmen, T.H. Grue, T. Børvik. Perforation of laminated glass: An experimental and numerical study. International Journal of Impact Engineering 2021, volume 156, 103922.
13. M. Reil, D. Morin, M. Langseth, O. Knoll. A novel tests set-up for validation of connector models subjected to static and impact loadings. International Journal of Impact Engineering 2021, Volume 158
14. I.G. Ringdalen, I.J.T. Jensen, C.D. Marioara, J. Friis. The Role of Grain Boundary Precipitates during Intergranular Fracture in 6xxx Series Aluminium Alloys. Metals 2021.
15. O. Vestrum, M. Langseth, T. Børvik. Finite element analysis of porous polymer coated pipelines subjected to impact. International Journal of Impact Engineering 2021, Volume 152
16. J. Xu, B. Holmedal, O.S. Hopperstad, K. Marthinsen. Experimental Characterization and Modelling of the PLC Effect in an AlMg-Alloy. Materials Science Forum 2021, Volume 1016 pp 188-193.

Conference contributions 2021

1. V. Andre, D. Morin, M. Costas, M. Langseth. Neural network representation of mechanical fasteners in large-scale analyses. 13th European LS-DYNA Conference 2021, 2021-10-05 - 2021-10-06
2. A. Antoniou, M. Kristoffersen, T. Børvik. Survey of four material models for ballistic simulations of high-strength concrete. 13th European LS-DYNA Conference 2021; 2021-10-05 - 2021-10-07
3. V. Aune, G. Valsamos, F. Casadei, M. Langseth, T. Børvik. Influence of fluid-structure interaction effects on the ductile fracture of blast-loaded steel plates. The European Physical Journal Conferences 2021, Volume 250.

4. K.A. Brekken, R. Kaufmann, V. Aune, T. Børvik. Shock tube testing of deformable structures: A novel experimental set-up. BSSM 15th International Conference on Advances in Experimental Mechanics; 2021-09-07 - 2021-09-09
5. E. Christiansen, C.D. Marioara, R. Holmestad. Deformed Al-Mg-Si alloys studied at the nanoscale. MRM2021- Materials Research Meeting; 2021-12-13 - 2021-12-17
6. E. Christiansen, C.D. Marioara, O.S. Hopperstad, R. Holmestad. Nanoscale characterisation of deformed Al-Mg-Si alloys. Thermec 2021 Virtual conference; 2021-06-01 - 2021-06-06
7. B.S. Elveli, T. Børvik, V. Aune. Influence of material properties on the performance of blast-loaded steel plates with pre-cut defects. The European Physical Journal Conferences 2021, Volume 250
8. R.M. Færgestad, J.K. Holmen, T. Berstad, T. Cardone, K.A. Ford, T. Børvik. Modelling and Simulation of Hypervelocity Impacts on Spacecraft in Low Earth Orbit. 13th European LS-DYNA Conference 2021; 2021-10-05 - 2021-10-07
9. H.M. Granum, D. Morin, T. Børvik, O.S. Hopperstad. A study on blast-loaded aluminium plates with crack-like defects subjected to blast loading. 13th European LS-DYNA Conference 2021; 2021-10-05 - 2021-10-07
10. J.K. Holmen, J. Johnsen, D. Morin, T. Børvik, M. Langseth. Calibration of *MAT_258 with a Lode dependent fracture surface and its application in bending of high-strength steel. 13th European LS-DYNA Conference 2021; 2021-10-05 - 2021-10-07
11. J. Johnsen, L.E.B. Dæhli, T. Børvik, O.S. Hopperstad. Experimental-numerical determination of the Taylor-Quinney coefficient. 13th European LS-DYNA Conference; 2021-10-05 - 2021-10-06
12. R. Kaufmann, B.C. Abrahamsen, Ø. Hellan, V. Aune. Full-field reconstruction of water slamming pressures. 74th Annual Meeting of the APS Division of Fluid Dynamics; 2021-11-21 - 2021-11-23
13. M. Kristoffersen, A. Minoretti, K.O. Hauge, T. Børvik. Blast loading of concrete pipes - Experiments and simulations. 25th International Congress of Theoretical and Applied Mechanics; 2021-08-22 - 2021-08-27
14. M. Kristoffersen, O.L. Toreskås, S. Dey, T. Børvik. Ballistic impact on concrete slabs: An experimental and numerical study. DYMAT 2021 – 13th International Conference on Mechanical and Physical Behaviour of Materials under Dynamic Loading (digital attendance); 2021-09-20 - 2021-09-24
15. K. Marthinsen, J. Xu. Characterization and modelling of the Portevin-Le Chatelier (PLC) effect in aluminium alloys. Online seminar Chongqing («111» and "International Joint Lab"); 2021-12-06 - 2021-12-06
16. K. Marthinsen,J. Xu, B. Holmedal, O.S. Hopperstad, T. Manik. Characterization and modelling of the Portevin-Le Chatelier (PLC) effect in aluminium alloys. The International Conference on the Physical Properties and Application of Advanced Materials (ICPMAT); 2021-09-18 - 2021-09-19
17. K. Marthinsen, J. Xu, B. Holmedal, O.S. Hopperstad, T. Manik. Experiments and constitutive modelling of the PLC effect at a wide range of strain rates and temperatures in an AlMg alloy (AA5182). Thermec'2021 Virtual Conference; 2021-06-01 - 2021-06-05
18. K. Osnes, T. Børvik, T.H. Grue, J.K. Holmen. Experimental tests and numerical simulations of ballistic impact on laminated glass. DYMAT 2021 - 13th International Conference on Mechanical and Physical Behaviour of Materials under Dynamic Loading (digital attendance); 2021-09-20 - 2021-09-24
19. K. Osnes, T. Børvik, S. Kreissl, J. D'haen. Modelling of Fracture Initiation and Post-Fracture Behaviour of Head Impact on Car Windshields. 13th European LS-DYNA Conference 2021, Ulm, Germany; 2021-10-05 - 2021-10-07
20. J.K. Sønstabø, K.U. Faksvåg, L. Jakobsen, A.H. Clausen. Modelling of Stainless Steel AISI 316L in Finite Element Simulations. ce/papers - Eurosteel 2021, Volume 4.(2-4) s. 1589-1598

PhD theses

1. Daniel Morton, Characterization and modeling of the mechanical behavior of polymer foam. ISBN 978-82-326-5699-8
2. Jianbin Xu, An experimental and numerical study of the Portevin-Le Chatelier effect in an AlMg alloy. ISBN 978-82-326-6740-6

A CRASH Course

When politicians knock and want to pay a visit, the SIMLab staff are always alert and proud to present how the Centre works with physical security. On 1st September, Parliamentary politicians Espen Barth Eide, Jorodd Asphjell and Eirik Sivertsen from the Labour Party were given a short introduction and demonstrations of our research activities. As CASA now approaches the wind-up period, researchers and politicians also took the opportunity to discuss future initiatives for the Centre.

Professor Magnus Langseth gave his presentation in the large hall, next to the impressive Pendulum Impactor – also known as the Kicking Machine. Senior engineers Trond Auestad and Tore Wisth had everything prepared beforehand. The engaged politicians got a quick demonstration of a 40 kph crash test of an aluminium profile.

Next, the group moved over to the Ballistic Impact lab (photo). This is Professor Tore Børvik´s domain, and he presented how they use the Gas gun for ballistic impact studies. A variety of projectile geometries can be fired here, with a maximum velocity of 1000 metres per second.

The Shock tube facility was the last stop on the group´s tour. Here, associate professor Vegard Aune explained the possibilities of the nearly 20-metre-long custom-made pipe for recording and measuring blast loads. The researchers subject aluminium, steel, glass, and concrete plates to blast loads in this facility.

The Complex CONCRETE

Several SFI CASA researchers shared a wide variety of news with global industry players at the LS-DYNA conference. Among them, Postdoc Andria Antoniou. She is one of the Centre's experts on the ballistic impact on concrete and works closely with Professor Tore Børvik and Research scientist Martin Kristoffersen.

The protection of critical infrastructure against ballistic impact scenarios is crucial for public safety. Concrete is the most common material in shielding barriers, but the design poses significant challenges. Thus, there is a great demand for accurate numerical models, especially for conditions involving high strain rates, high triaxial pressures and complicated fracture modes. Accurate data reflecting the behaviour of the material under such conditions are rare and difficult to produce. LS-DYNA is a multi-physics software package capable of simulating the complex deformation behaviour of structures.

Andria Antoniou presented a new survey of four material models for ballistic simulations of high-strength concrete. Three of the most used concrete models are available in LS-DYNA. The primary motivation behind the study is to investigate the accuracy of the default material cards to predict the ballistic impact response of concrete slabs.

Publications on concurrent projects

1. V. Espeseth, D. Morin, J. Faleskog, T. Børvik, O.S. Hopperstad. A numerical study of a size-dependent finite-element based unit cell with primary and secondary voids. Journal of the Mechanics and Physics of Solids, 2021.
2. M.J. Forrestal, T.L. Warren, J.K. Holmen. Ballistic-Limit Velocities for 7.62 mm APM2 Bullets and Aluminum Alloy Armor Plates. Journal of Dynamic Behavior of Materials 2021, volume 7 (4) pp. 624-627
3. B.H. Frodal, S. Thomesen, T. Børvik, O.S. Hopperstad. On the coupling of damage and single crystal plasticity for ductile polycrystalline materials. International Journal of Plasticity 2021, Volume 142.
4. H. Granum, O.R. Myhr, T. Børvik, O.S. Hopperstad. Effect of pre-stretching on the mechanical behaviour of three artificially aged 6xxx series aluminium alloys. Materials Today Communications 2021, Volume 27.
5. M. Khadyko, B.H. Frodal, O.S. Hopperstad. Finite element simulation of ductile fracture in polycrystalline materials using a regularized porous crystal plasticity model. International Journal of Fracture 2021 228 15–31.
6. C.D. Marioara, T. Børvik, O.S. Hopperstad. The relation between grain boundary precipitate formation and adjacent grain orientations in Al-Mg-Si(-Cu) alloys. Philosophical Magazine Letters 2021, Volume 101.(9) pp 370-379
7. T. Morgeneyer, M. Khadyko, A. Buljac, L. Helfen, F. Hild, A. Benallal, T. Børvik, O.S. Hopperstad. On crystallographic aspects of heterogeneous plastic flow during ductile tearing: 3D measurements and crystal plasticity simulations for AA7075-T651. International Journal of Plasticity 144 (2021) 103028.
8. S. Thomesen, O.S. Hopperstad, T. Børvik. Anisotropic plasticity and fracture of three 6000-series aluminum alloys. Metals 11 (2021) 557.
9. A.J. Tomstad, S. Thomesen, T. Børvik, O.S. Hopperstad. Effects of constituent particle content on ductile fracture in isotropic and anisotropic 6000-series aluminium alloys. Materials Science & Engineering: A 2021, Volume 820.
10. K. Qvale, O.Reiso, U.H. Tundal, C. Marioara, O.S. Hopperstad. An experimental study on pre-strained double-chamber 6000-series aluminium profiles subjected to quasi-static and dynamic axial loading. Thin-Walled Structures 2021;158: 107160.

Conference contributions

1. B.H. Frodal, S. Thomesen, T. Børvik, O.S. Hopperstad. On the coupling of damage and single crystal plasticity for ductile polycrystalline materials. 25th International Congress of Theoretical and Applied Mechanics (ICTAM); 2021-08-22 - 2021-08-27
2. O.S. Hopperstad, B.H. Frodal, S. Thomesen, T. Børvik. Plastic anisotropy and fracture of 6000-series aluminium alloys: an experimental and numerical study. COBEM 2021. 26th International Congress of Mechanical Engineering, Brazil (digital conference); 2021-11-22 - 2021-11-26
3. O.S. Hopperstad, S. Thomesen, B.H. Frodal, A.J. Tomstad, T. Børvik. Plastic flow and fracture in anisotropic aluminium alloys: Experiments, modelling and simulation. 2nd International Workshop on Plasticity, Damage and Fracture of Engineering Materials (IWPDF 2021)); 2021-08-18 - 2021-08-20

Annual accounts

SFI CASA FUNDING 2021 (ALL FIGURES IN 1000 NOK)

Item	Host NTNU	Research partner SINTEF	Public partners	Industrial partners	RCN grant	Total funding
Research programmes	7390	1100	3320	6363	10590	28763
Equipment			48	286		334
Administration	1000		782	3151		4933
Total budget	8390	1100	4150	9800	10590	34030

SFI CASA COSTS 2021 (ALL FIGURES IN 1000 NOK)

Item	Host NTNU	Research partner SINTEF	Public partners	Industrial partners	Total cost
Research programmes	21443	3970	700	2650	28763
Equipment	334				334
Administration	4833	100			4933
Total budget	26610	4070	700	2650	34030

A MILESTONE for the Shock tube

Composites are among the essential materials in designing and manufacturing aeronautical structures. More than 50 per cent of modern aircraft consists of these lightweight and high-temperature resistant materials. Ramón del Cuvillo Mezquita tests and models composites under extreme loads.

«Despite their high stiffness and high strength-to-weight ratio, these materials are quite vulnerable to impact loading. The impact loads could be anything from bird strikes to hail, tyre rubber or metal fragments in this context. Therefore, damage tolerance is a critical safety issue for the design of primary aircraft structures», del Cuvillo explains.

He is a PhD candidate at the University Carlos II de Madrid. He thinks he is lucky to carry out a series of tests in the SIMLab Shock tube facility (SSTF) at SFI CASA. «Beforehand, we did not quite know what to expect or what to obtain in the SSTF. By now, we have tested 15 plates, which has given us a lot of information. All of us are very happy», Del Cuvillo said just before heading back to Spain for Christmas.

Associate professor Vegard Aune agrees: «It is great that the SSTF attracts scholars outside Norway. We built it for exactly the purpose of Ramon's tests, namely small-scale blast testing of flexible structures in controlled, laboratory environments. This test campaign turned out to be very useful. Also, it is a new milestone for the SSTF because it was the first time that we tested composites», Aune adds.

Core Team Members Meet the GREEN SHIFT Challenges with new SFI PhysMet

On 12 January 2021, NTNU celebrated the official opening of SFI PhysMet - A Center for a Sustainable and Competitive Metal Industry.
Professor Knut Marthinsen is the Centre´s director. Professor Randi Holmestad leads «Multi-scale material analyses», one of the new SFI´s 5 key research areas. Both Marthinsen and Holmestad hold positions as Core Team members of CASA. Also, PhysMet´s interdisciplinary research involves other scientists from NTNU and SINTEF working closely with our Centre. Thus, SFI PhysMet is a true relative of SFI CASA.

ACCELERATING THE GREEN SHIFT

More materials must be recycled, and production must adapt to a world where things are reused. Knut Marthinsen and his staff aim to be a world-leading research centre in the field. Physical metallurgists study the properties of metals and alloys, such as mechanical strength and forming properties. They want to develop a fundament supporting the national metal industry to accelerate the transformation towards more sustainable and cost-efficient production. In addition to collaboration on reducing the CO^2 footprints, PhysMet will develop sustainable solutions for offshore wind turbines, construction of large bridge structures and new processes that make materials and alloys better suited for recycling and reuse.

COMPLYING WITH THE REQUIREMENTS

The transition to greener processes has been going on for some time already in the metal industry. However, the awareness of the considerable potential for further reduction in emissions is growing. Both Norwegian and international metal-based industries must comply with national and international rules and requirements for increased use of recycled metal in materials and products.
Knut Marthinsen has been a professor of physical metallurgy at the Department of Materials Science and Engineering (DMSE) since 1998. His current research activities mainly relate to developing and applying physically based computer models for the evolution of microstructure and texture during thermomechanical processing of aluminium alloys. This work includes models for precipitation, work hardening, recrystallization and grain growth.

PHYSMET´S FIVE RESEARCH AREAS:

SFI PhysMet has funding from 2020-2028, and the Centre has five research areas (RA):

- Multi-scale material analyses
- Scale and process bridging methodologies
- Sustainable and high-performance material development
- Innovative processing and joining methods
- Data, sharing and digital platforms

SFI PhysMet´s industrial partners are Equinor, Thermo-Calc Software, Benteler, Hydro, Elkem, Norwegian Public Road Authority, and Raufoss Technology.

What is an SFI, what is SIMLab, what is CASA...

SFI is a funding scheme

SFI, Centre for Research-based Innovation, is a funding scheme administered by the Research Council of Norway (RCN). The main objective for the SFIs is to increase the capability of business to innovate by focusing on long-term research. The idea is to forge close alliances between researchintensive enterprises and prominent research groups. The host institution for an SFI can be a university, a university college, a research institute or an enterprise with a strong research activity.
The partners (enterprises, public organisations and other research institutions) must contribute to the centre in the form of funding, facilities, competence and their own efforts throughout the life cycle of the centre. The life cycle is eight years. On the average, each centre receives roughly 12 MNOK per year from RCN. The host institution and partners must contribute with at least the same amount.

SIMLab is a research group

Structural Impact Laboratory, SIMLab, is a research group at the Department of Structural Engineering, NTNU. From 2007 to 2014, SIMLab hosted an SFI with the same name, SFI SIMLab.
This double use of the name sometimes causes confusion, but now you know: SFI SIMLab is history; the SIMLab research group is alive and kicking. All the more comforting, since the group carries with it all the expertise that brought SFI SIMLab to a world-leading position in the design of crashworthy and protective structures.

CASA is an SFI

CASA, Centre for Advanced Structural Analysis, is the name of the current SFI hosted by the SIMLab research group. It was officially established on 1 July 2015. The vision of SFI CASA is to establish a world-leading centre for multi-scale testing, modelling and simulation of materials and structures for industrial applications. In doing so, CASA goes further down in scale to nano level and wider in scope than SFI SIMLab did.

Fun at work: From left Lars Edvard Blystad Dæhli. Magnus Langseth, Tore Wisth and Tore Børvik (Photo: Sølvi W. Normannsen).

OUR VISION:

"To establish a world-leading centre for multiscale testing, modelling and simulation of materials and structures for industrial applications."

CASA

Centre for Advanced Structural Analysis