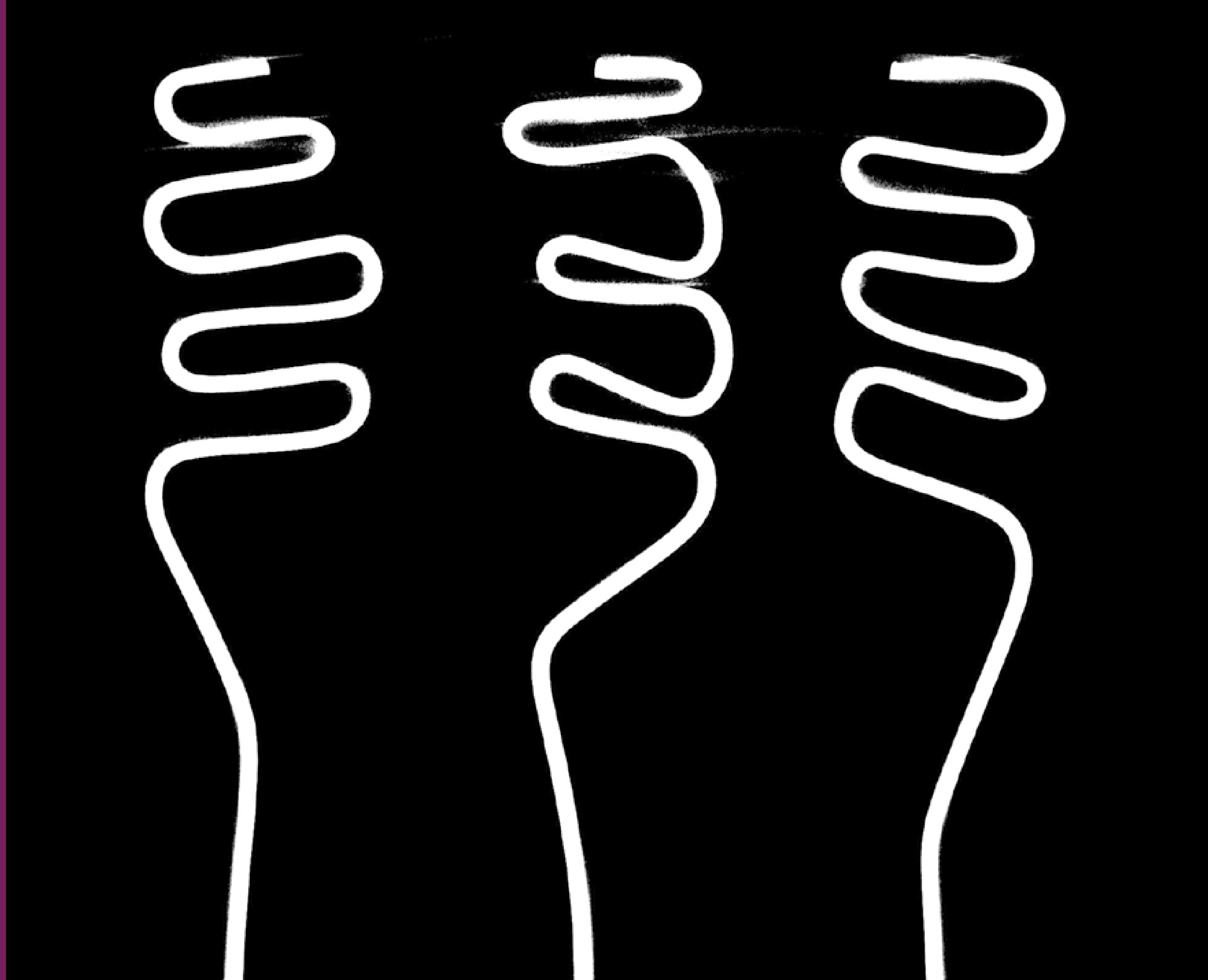
CASA

Annual Report 2019

Centre for Advanced Structural Analysis



sfi Centre for Research-based Innovation

SINTEF

NTNU

The former Norwegian Minister of public security Ingvil Smines Tybring-Gjedde was responsible for civil protection, preparedness and the Polar areas in Norway. In May 2019 she came to SFI CASA on The Centre´s invitation to learn more about how the research aims to improve the survivability of people and vital infrastructure against any given threat.
(Photo: Sølvi W. Normannsen)

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COVER:
Slice of an X-ray CT scan of a crushed double-chamber aluminium crash box, showing progressive buckling of the profile walls. The experiment is part of PhD candidate Kristin Qvale's work at concurrent project FractAl: «Microstructure-based modelling and simulation of ductile fracture in aluminium alloys».

GRAPHIC DESIGN:
NTNU Grafisk senter

CONTENTS

Summary 4
Vision and Objective 5
Goals and Research Questions 6
Research Programmes 7
Research Methodology 8
Research Organization 9
Cooperation Within the Centre 14
International Cooperation and Leading-edge Research 16
Toppforsk Project FractAl 20
The Midway Evaluation 21
Meet the Doctors 23
- Unravelling the Chaos in the Interior of Polymers 24
- Rocking Around at the Nanoscale 26
- Digging Deep for Damage and Failure 28
- Spitting Gold to Strengthen Steels 30
- Bright Glass Comes with a Shady Side 32
- The Provider of Inside Information 34
- Simulations Getting Closer to an Actual Vehicle Crash 36
Test Facilities 38
Visibility 40
Personnel 44
Publications & Annual accounts 48
What is SFI, what is SIMLab, what is CASA 53

SUMMARY

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 14 industrial partners.

SFI CASA's board comprises of representatives from all the partners. A director heads the daily operation, assisted by a core team and programme heads. CASA's Industrial Reference Group is established to monitor and facilitate industrial implementation of the results generated in the Centre. A Scientific Advisory Board of international experts has been appointed to provide 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 technical meetings and seminars linked to the different research programmes throughout 2019. The technical meetings are an important arena for discussions with the industrial partners and help cooperation and communication within the research programmes. The annual work plans are generated on the basis of discussions at the technical meetings. The Industrial Reference Group had several telephone meetings and met in Guyancourt, France, on 17 September. Finally, the Board had a seminar and Board meeting on 18-19 September hosted by Renault in Guyancourt, France

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 five international partners (Audi, BMW, Honda, Renault, and Toyota).

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 this respect, 2019 has been a good year. We have had a great deal of publicity on different media platforms.

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. We continued this work in 2019.

Visibility in the research community is also important. The CASA researchers published 16 journal articles, 3 conference proceedings articles and 1 encyclopedia article during 2019. They gave 39 conference presentations. In addition, the research group published 6 journal articles and gave 9 conference presentations related to concurrent projects.

PhD defences

7 PhD candidates defended their theses in 2019:

Petter Henrik Holmström, Emil Christiansen, Bjørn Håkon Frodal, Christian Oen Paulsen, Karoline Osnes, Susanne Thomesen (concurrent project FractAl) and Matthias Reil.

VISION AND OBJECTIVE

Vision

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

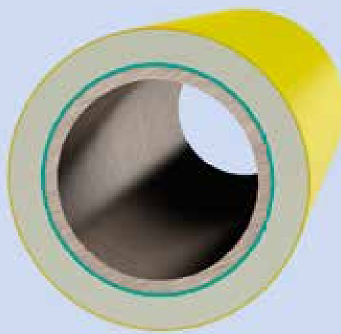
Objective

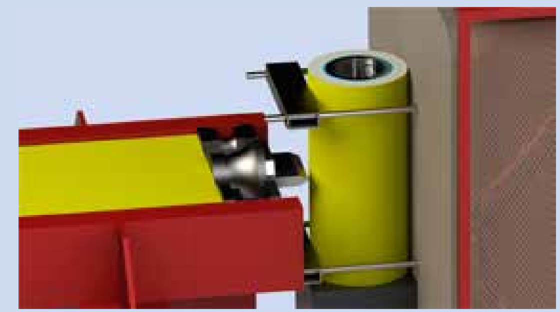
The Centre will develop validated computational tools for innovation together with and for partners in the oil and gas industry, the transportation industry, and in industrial and public enterprises working with physical security. Even though these partners represent different business sectors, they have similar needs in advanced structural analysis. 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 the main objective for CASA is:

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

GOALS AND RESEARCH QUESTIONS






Porous polymeric coating is often used as anti-corrosion and thermal insulation on subsea steel pipelines. These are exposed to the risk of impact from fishing trawls or anchors. PhD candidate Ole Vestrum studies impact on these pipelines. His work includes an extensive series of quasi-static and impact indentation tests in the kicking machine on full-scale pipeline samples in cooperation with Equinor. *(See next page)*

Goals

The main quantitative goals of the Centre are as follows:

Industrial: 1) To develop methods and tools for implementation at the user partners. 2) To ensure the transfer of technology across business sectors. 3) To arrange courses and case study seminars at the user partners. 4) To facilitate concurrent research projects with the user partners and cooperation between partners. 5) To facilitate employment of post docs, MSc and PhD candidates at the user partners to strengthen the industrial implementation.

Academic: 1) To graduate at least 20 PhD candidates and employ 5-10 post docs. 2) To graduate 100-200 MSc students. 3) To attract 5-10 non-Norwegian professors/scientists to the Centre. 4) To publish 100-150 papers in international peer-reviewed journals in addition to conference papers. 5) To arrange two international conferences.

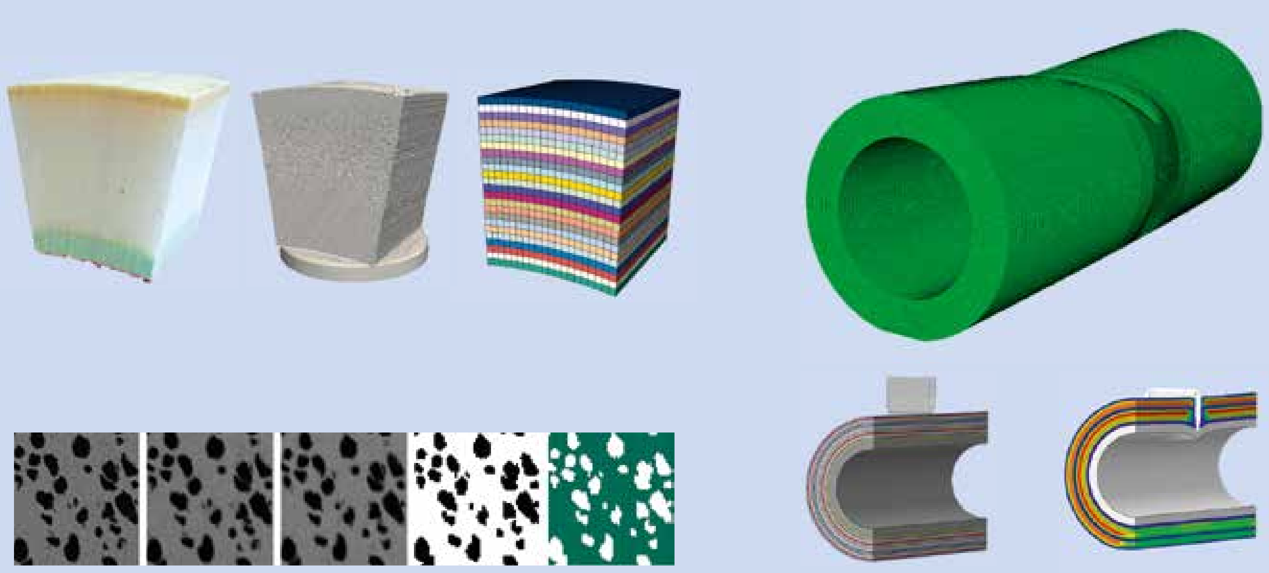
Media: 1) To implement a strategy for popular science presentations of the research activities in magazines, newspapers, on television, radio and the web. 2) To establish a media strategy where the female researchers are made particularly visible in order to recruit female PhDs and post docs and contribute to a more even gender balance in this research field.

Research questions

Discussions with the partners have revealed that more extensive use of advanced numerical simulations will improve their competitiveness in making cost-effective, safe and environmentally friendly structures and products. This industrial need is the basis for the three research questions defined as the point-of-departure for the research activities in CASA.

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 material, 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.



PhD Candidate Ole Vestrum has introduced a new modelling approach. Three-dimensional CT images of porous coating samples are converted into finite element models to study how the pore structure affects the mechanical behaviour. The knowledge is used to derive a constitutive material model applicable in full-scale finite element simulations.

Research programmes

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

Metallic Materials: This programme will develop 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 will be on aluminium alloys and steels. In many critical structural applications, material properties beyond standard testing conditions are required; hence high and low temperatures, high pressures (from blast waves or water depths) and elevated rates of strain (including shock loading) will be given special attention.

Polymeric Materials: This research programme will develop 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 will be 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 will provide 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 will develop advanced computational tools and establish validated modelling guidelines for computer-aided design of safer and more cost-effective structures. Another objective will be 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 will not be on traditional fortification installations, but 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.

RESEARCH METHODOLOGY

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 is always 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 sufficiently 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, verification 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.

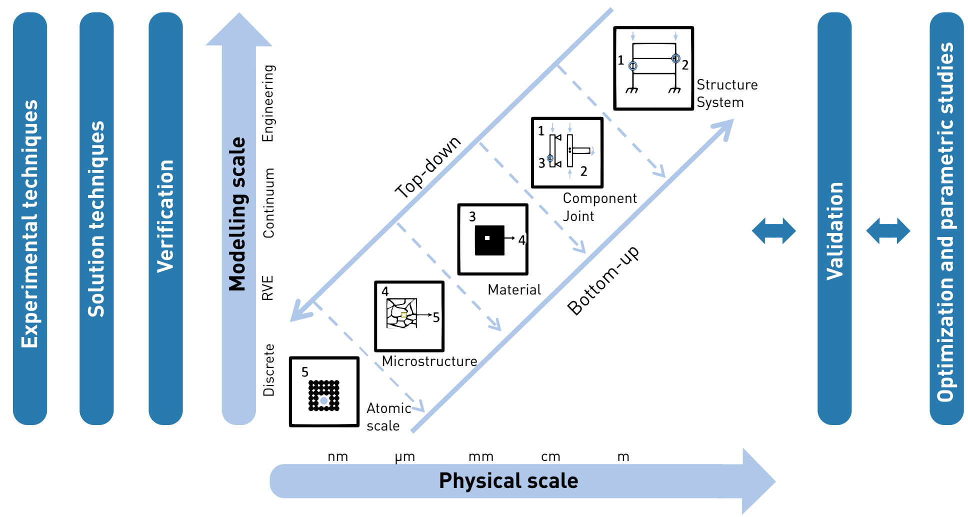


Figure 1: Research methodology.

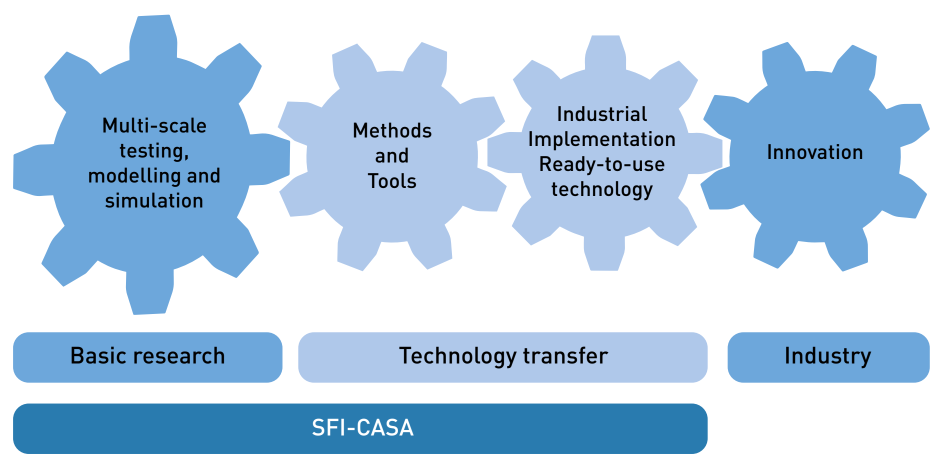


Figure 2: Structure of research, technology transfer and industrial implementation.

RESEARCH ORGANIZATION

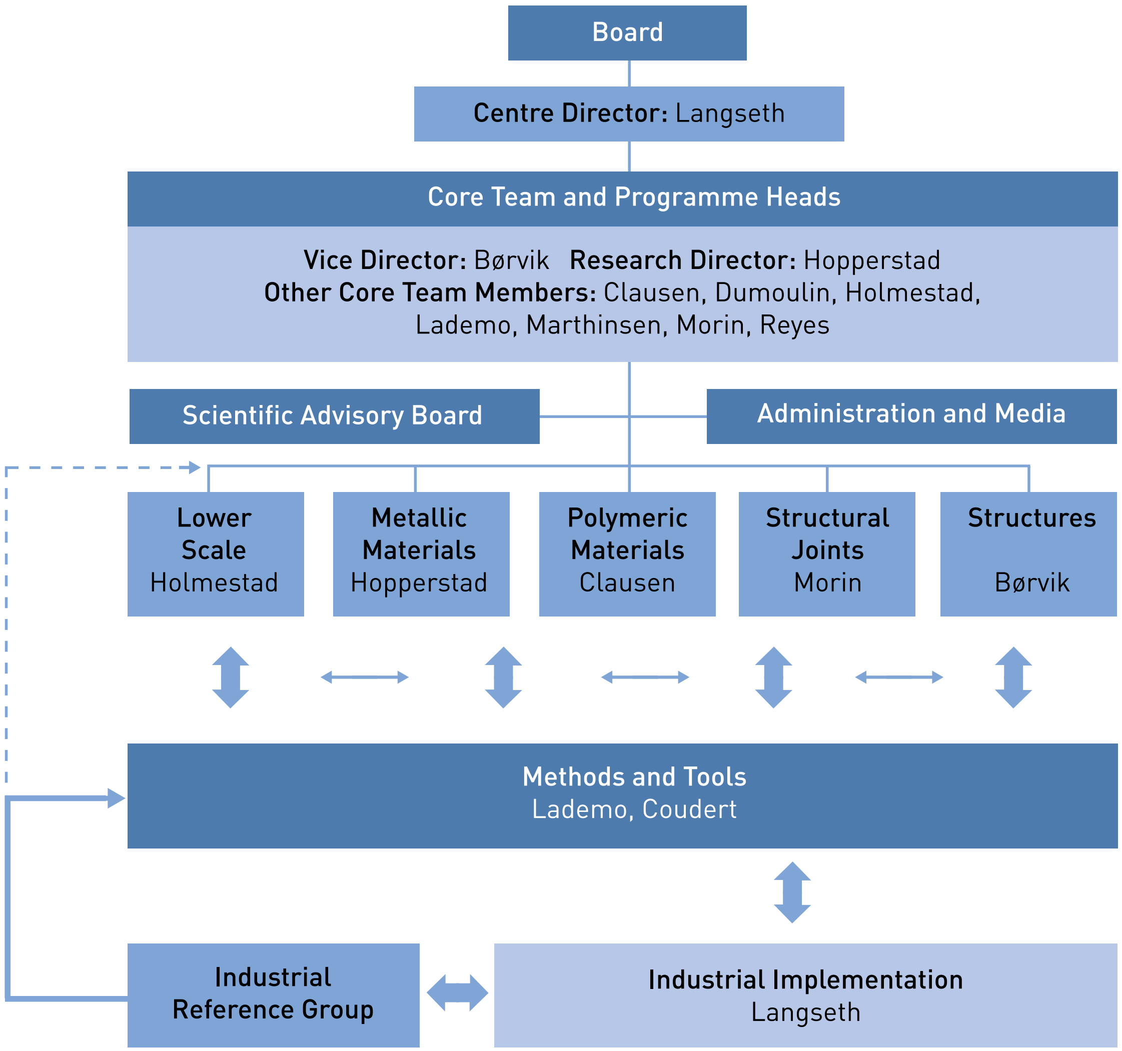


Figure 3: Structure of the organization in 2019.

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 scientific and strategic advice.

Each of the five research programmes is led by a programme head. These programme heads are responsible for the verification and validation of the developed models and technology. Cooperation across the research programmes ensures the transfer of technology and allows 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.

The Board

Anders Artelius, Benteler Automotive Raufoss AS
Olav Bolland, NTNU (Chair)
Jørn Brunsell, Norwegian Defence Estates Agency
Ole Daaland, Hydro Aluminium AS
Michael Floer, BMW Group
Jens Christian Holst, Norwegian National Security Authority
Agnes Marie Horn, DNV GL AS
Rolf Jullum, Ministry of Local Government and Modernisation
Andreas Koukal, Audi AG
Tania Waage Leporowski, Multiconsult Norge AS
Satoru Miyagano, Toyota Motor Europe
Brian O'Hara, Honda R&D Americas Inc.
Mario Polanco-Loria, Equinor Energy AS
Rudie Spooren, SINTEF Industry
Pablo Wilson, Renault
Gina Ytteborg, Norwegian Public Roads Administration

Scientific Advisory Board

Professor Ahmed Benallal, LMT/ENS Paris-Saclay, France
Professor Em. David Embury, McMaster University, Canada
Professor Jonas Faleskog, Royal Institute of Technology, Sweden
Professor Norman Fleck, University of Cambridge, UK
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
Odd-Geir Lademo, Research Manager, SINTEF Industry*
Knut Marthinsen, Professor, Dept. of Materials Science and Engineering, NTNU
David Morin, Associate Professor, Dept. of Structural Engineering, NTNU
Aase Gavina Reyes, Professor, OsloMet**

*Adjunct Professor at Dept. of Structural Engineering (20% position)
** Professor at Dept. of Structural Engineering (20 % position)

Scientific staff

Vegard Aune, Associate Professor, Dept. Of Structural Engineering, NTNU
Torodd Berstad, Researcher, Dept. of Structural Engineering, NTNU
Miguel Costas, Researcher, Dept. of Structural Engineering, NTNU
Virgile Delhaye, SINTEF Industry
Borja Erice, Researcher, Dept. of Structural Engineering, NTNU
Egil Fagerholt, Researcher, Dept. of Structural Engineering, NTNU*
Petter Holmström, Researcher, Dept. of Structural Engineering, NTNU
Martin Kristoffersen, Researcher, Dept. of Structural Engineering, NTNU
Calin Marioara, Senior Research Scientist, SINTEF Industry
Inga Gudem Ringdalen, SINTEF Industry
Afaf Saai, 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
Laila Irene Larsen, Accountant, Dept. of Structural Engineering, NTNU
Sølvi W. Normannsen, Communication Officer, Dept. of Structural Engineering, NTNU
Tore Wisth, Senior Engineer, Dept. of Structural Engineering, NTNU

Partners in 2019

Host institution

NTNU

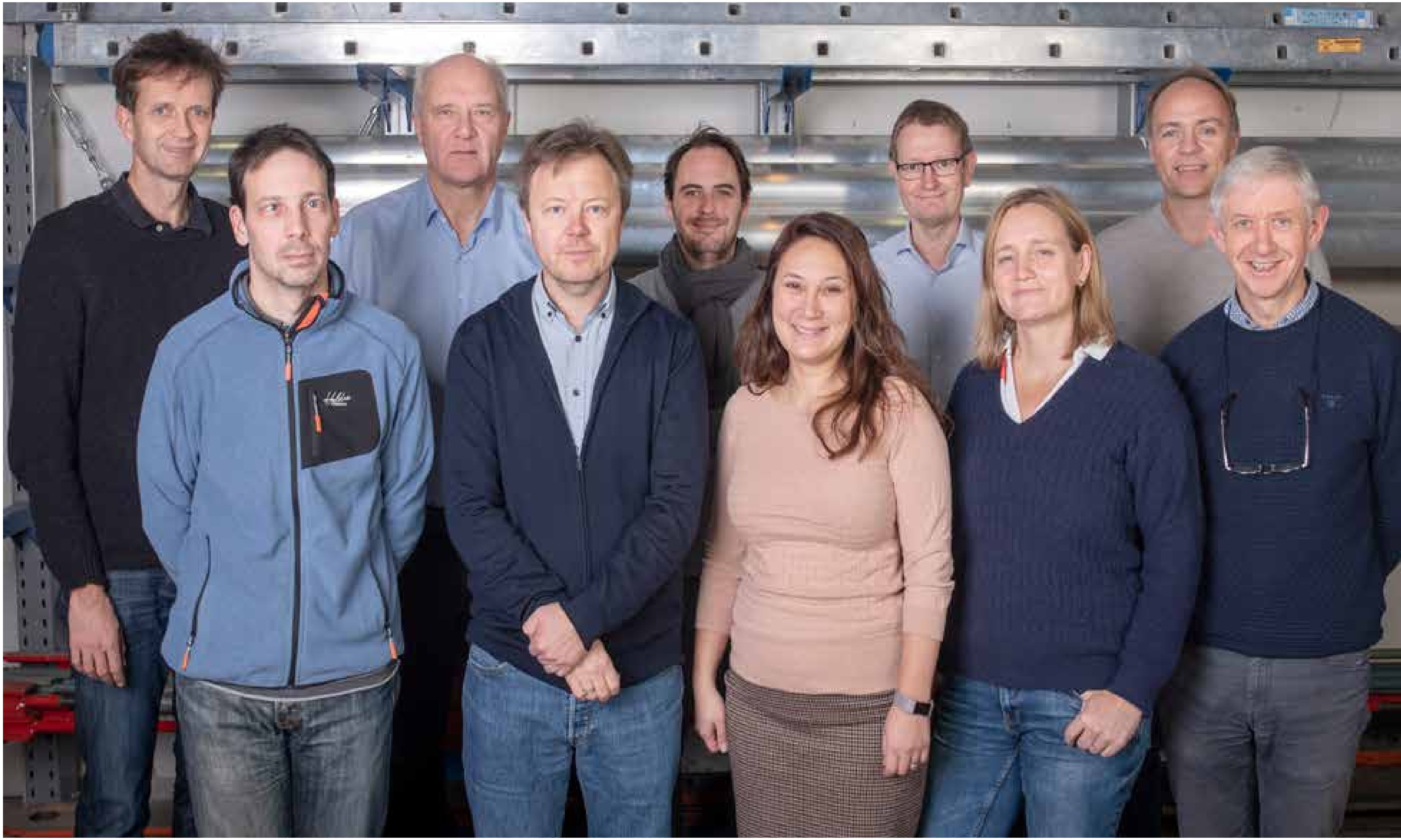
Research partner

SINTEF Industry

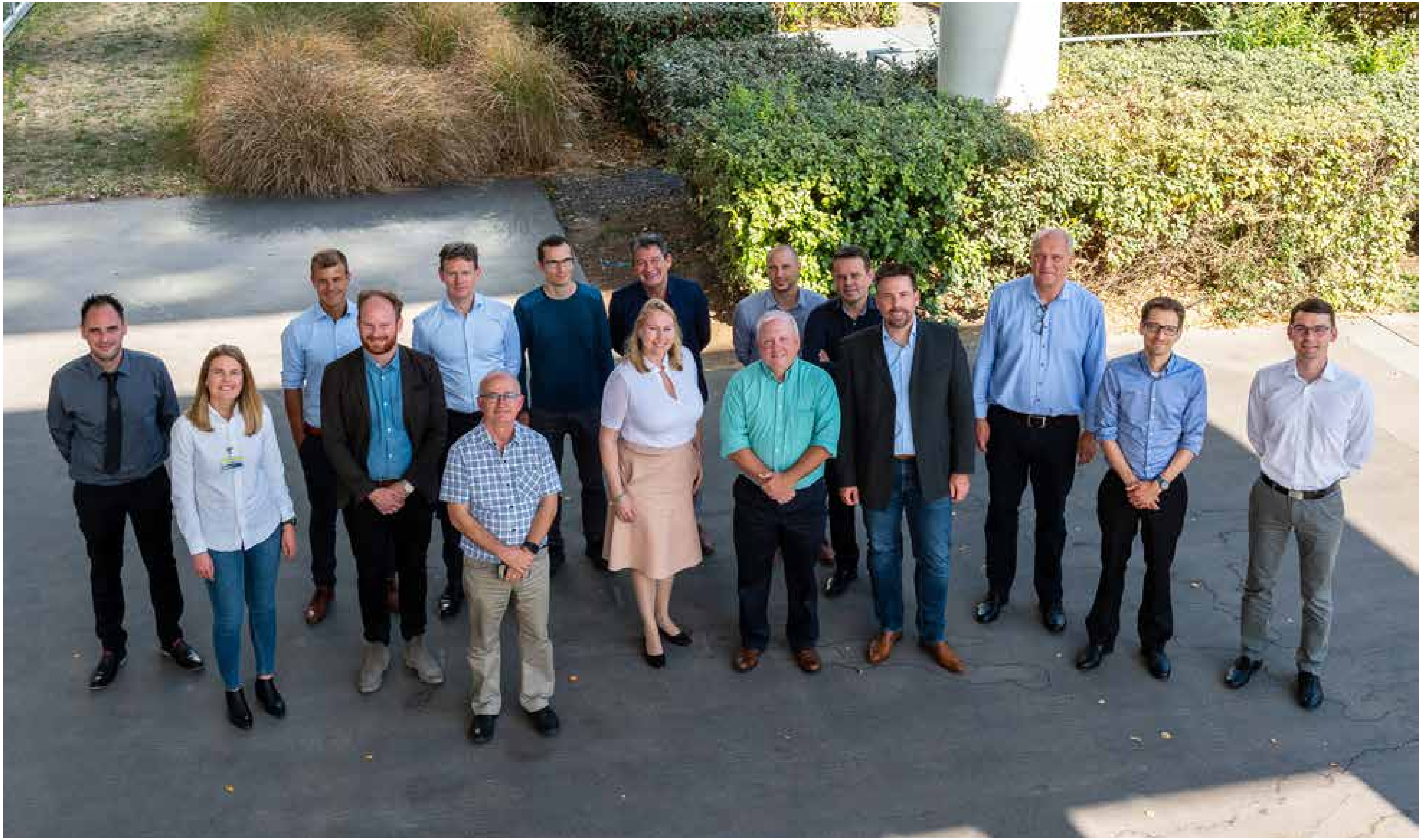
Industrial partners

Audi AG
Benteler Automotive Raufoss AS
BMW Group
DNV GL AS
Equinor Energy AS
Honda R&D Americas Inc.
Hydro Aluminium AS
Ministry of Local Government and Modernisation
Multiconsult Norge AS
Norwegian Defence Estates Agency
Norwegian National Security Authority
Norwegian Public Roads Administration
Renault
Toyota Motor Europe

The Board, gathered in Guyancourt, France on 19 September 2019. *From left: Nicolas Neumann (Multiconsult), Agnes Marie Horn (DNV GL), Rudie Spooren (SINTEF), Jørn Brunsell (Norwegian Defence Estates Agency), Magnus Langseth (NTNU), Jean François Vittori (Renault), Olav Bolland (NTNU, Chair), Brian O'Hara (Honda R&D Americas), Ole Daaland (Hydro), Mario Polanco-Loria (Equinor), Arjan Strating (Audi), Jens Christian Holst (Norwegian National Security Authority), Sebastian Kreissl (BMW), Rolf Jullum (Ministry of Local Government and Modernisation), and Lukas Schulenberg (Audi).* *(Photo: Jean-Christophe Mounoury – Communication Renault)*



CASA CORE TEAM: *From left: Arild Holm Clausen, Stéphane Dumoulin, Magnus Langseth, Tore Børvik, David Morin, Aase Reyes, Odd Sture Hopperstad, Randi Holmestad, Odd-Geir Lademo, Knut Marthinsen.* *(Photo: Lena Knutli).*



Industrial Reference Group. *From left: David Morin (NTNU), Solveig Heggelund (Norwegian Defence Estates Agency), Lukas Schulenberg (Audi), Knut Gaarder Rakvåg (Multiconsult), Jens Christian Holst (Norwegian National Security Authority), Jean François Vittori (Renault), Térence Coudert (SINTEF), Agnes Marie Horn (DNV GL), Mario Polanco-Loria (Equinor), Eric DeHoff (Honda), Andreas Assisi (Hydro), Björn Olsson (Hydro), Arjan Strating, (Audi), Magnus Langseth (NTNU), Sebastian Kreissl (BMW), and Jakub Galazka (Toyota Motor Europe).* *(Photo: Jean-Cristophe Mounoury - Communication Renault)*

COOPERATION WITHIN THE CENTRE

Partners Gathered at Renault in Guyancourt

The CASA team and its partners gathered at the Technocentre Renault in Guyancourt, France, on 17-19 September.

On the agenda was an assembly for the Industrial Reference Group (IRG). The board met for a seminar and meeting, and there were also technical sessions on aluminium and steel research.
The IRG meeting on Tuesday 17 September included a status report from the partners, involving examples on the implementation strategy of the host Renault. The group further discussed future priorities linked to research and implementation. The Midway Evaluation by the Research Council of Norway was also on the IRG´s agenda.
Finally, CASA challenged the IRG representatives about what they expect to be in the final delivery at the end of the period of the Centre.

On the following day, SFI CASA professors Tore Børvik and Odd Sture Hopperstad, researcher Borja Erice and Associate Professor David Morin presented ongoing research on metallic materials and structures. The partners also received status reports on the activities linked to the Centre´s six research programmes and a presentation on the Centre´s communication work.
The Board of SFI CASA reserved Thursday 19 September for their meeting.

Top left: Jens Christian Holst (Norwegian National Security Authority) (left) and Brian O´Hara (Honda R&D Americas). Right: Tore Børvik (NTNU) and Arjan Strating (Audi). Below from left: Agnes Marie Horn (DNV-GL), Borja Erice (NTNU), Mario-Polanco-Loria (Equinor) and Erling Østby (DNV-GL).

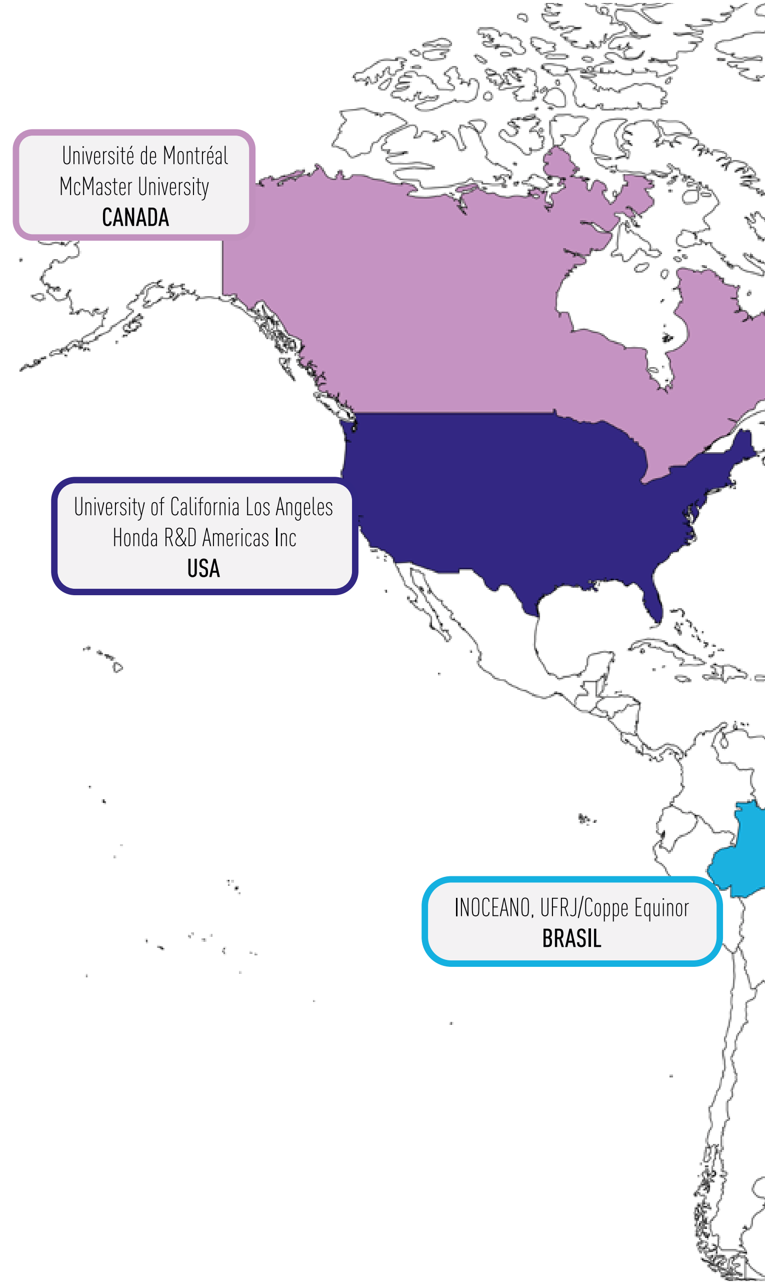
Top left: Sebastian Kreissl (BMW) and Jean Francois Vittori (Renault). Topp middle: Jørn Brunsell (Norwegian Defence Estates Agency), Agnes Horn (DNV-GL), Nicolas Neumann (Multiconsult) and Rolf Jullum (Ministry of Local Government and Modernisation). Top right: seminar dinner. Bottom left: Arjan Strating (Audi) and Magnus Langseth (NTNU). Right: Mario Polanco-Loria (Equinor).
(Photos: Sølvi W. Normannsen, NTNU)

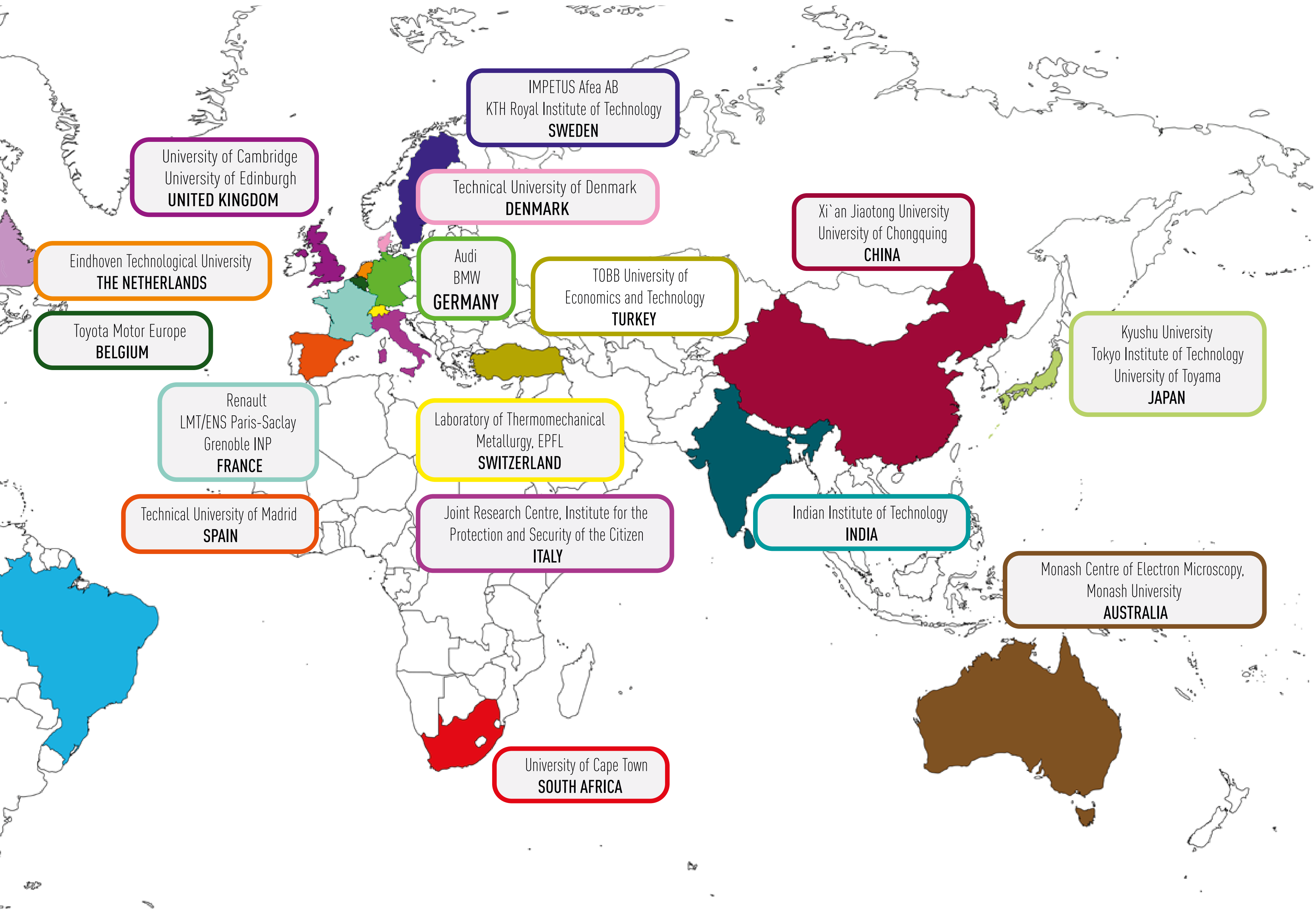
INTERNATIONAL COOPERATION AND LEADING-EDGE RESEARCH

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 five companies from outside Norway (Audi, BMW, Honda, Renault, and Toyota). 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. Two new members were invited to the SAB in 2019; Professor Patricia Verleysen from Ghent University in Belgium, and Professor Stefanie Reese from Aachen University in Germany.




IMPETUS Afea AB
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SWEDEN
University of Cambridge
University of Edinburgh
UNITED KINGDOM
Technical University of Denmark
DENMARK
Xi`an Jiaotong University
University of Chongquing
CHINA
Eindhoven Technological University
THE NETHERLANDS
Audi
BMW
GERMANY
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Economics and Technology
TURKEY
Kyushu University
Tokyo Institute of Technology
University of Toyama
JAPAN
Toyota Motor Europe
BELGIUM
Renault
LMT/ENS Paris-Saclay
Grenoble INP
FRANCE
Laboratory of Thermomechanical
Metallurgy, EPFL
SWITZERLAND
Technical University of Madrid
SPAIN
Joint Research Centre, Institute for the
Protection and Security of the Citizen
ITALY
Indian Institute of Technology
INDIA
Monash Centre of Electron Microscopy,
Monash University
AUSTRALIA
University of Cape Town
SOUTH AFRICA

The Board seminar in Guyancourt , France in September: *From left: Brian O´Hara (Honda R&D Americas), Arjan Strating (Audi), Sølvi W. Normannsen (NTNU), Laurent Rougier (Renault), Eric DeHoff (Honda R&D Americas), Cedric Bouton (Renault), Jørn Brunsell (Norwegian Defence Estates Agency), Marie Bjørshol (Multiconsult), Espen Tuveng (Multiconsult), Shintaro Kosaka (Toyota), Olav Bolland (NTNU), Borja Erice (NTNU), Odd Sture Hopperstad (NTNU), Andreas Assisi (Hydro), Rudie Spooren (SINTEF Industry), Christian Holst (Norwegian National Security Authority), Arild Holm Clausen (NTNU), Mario Polanco-Loria (Equinor), Peter Karlsaune (NTNU), Christine Royer (Renault), David Morin (NTNU).*

Yvan Chastel (Renault), Christophe Grolleron (Renault), Jean François Vittori (Renault), Magnus Langseth (NTNU), Agnes Marie Horn (DNV-GL), Knut Gaarder Rakvåg (Multiconsult), Terence Coudert (SINTEF Industry), Randi Holmestad (NTNU), Erling Østby (DNV-GL), Tore Børvik (NTNU), Björn Olsson (Hydro), Ole Runar Myhr (Hydro), Lukas Schulenberg (Audi), Nicolas Neumann (Multiconsult), Jakub Galazka (Toyota Motor Europe), Rolf Jullum (Ministry of Local Government and Administration), Sebastian Kreissl (BMW), Jens

(Photo: Jean-Christophe Mounoury – Communication Renault)

Toppforsk Project FractAl:

A New Way to Design Aluminium Structures

FractAl deals with building a basic understanding of ductile fracture in aluminium alloys. A new modelling framework enables designers and engineers to select the most suitable aluminium alloy for a given structure. The outcome is fewer time-consuming and costly mechanical tests.

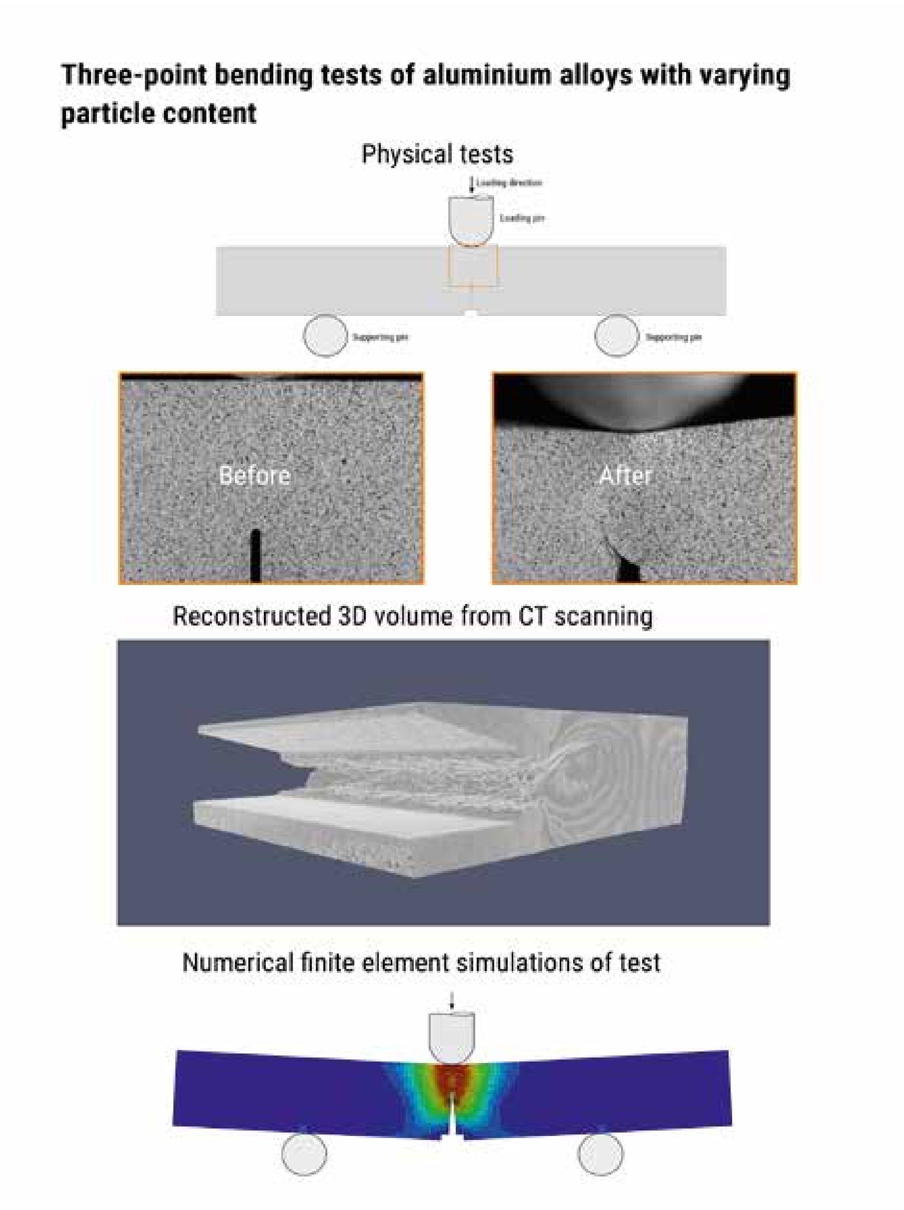
Toppforsk funding is a targeted initiative for providing substantial, long-term support to research groups with the potential to reach the top of their field internationally.
When the program was launched in 2016, Prime Minister Erna Solberg pointed out that the project is a key step in cultivating more world-leading academic groups in Norway. Funding is only being allocated to projects that have received the highest score after review by international referee panels.

The Toppforsk project FractAl started in August 2016 and lasts for 5 years. It is a concurrent project to SFI CASA, and the activities are closely coordinated 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 material's strength and ductility are important 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 ductility of the material. This can increase the risk of structural failure. Therefore, it is important to have good models for 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 less time-consuming and costly mechanical tests. The framework can also be used to tailor alloys with ideal strength and ductility of a given structure. This could pave the way for a completely novel method of designing aluminium structures.
The results obtained in FractAl are implemented in the SIMLab Tool Box and will thus be made available to the partners of CASA as well as for other industries.

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.

Currently 4 PhD candidates and 2 post docs work together with the core team. Professors Jonas Faleskog from KTH in Stockholm and Ahmed Benallal from ENS Paris-Saclay in Paris also take part in the project. Mikhail Khadyko was researcher in FractAl until the fall 2018 when he was employed as associate professor at UiT The Arctic University of Norway in Narvik. Susanne Thomesen defended her PhD thesis within the FractAl project in the fall 2019 and is now working as a post doc in CASA.



THE **MIDWAY** EVALUATION

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MIDWAY EVALUATION

«An Excellent Competence Centre»

For CASA, the midway evaluation of the SFI scheme could hardly have been more positive.

The main conclusion from the international experts that scrutinized CASA in March 2019 was clear: «This is an excellent competence centre with many examples of best practice in its research, research training, organization, and industry support operations».

No magic tricks

The midway evaluation involves all 17 centres in the 3rd SFI scheme. For CASA, there was only one recommendation which was a well-known Achilles heel: the weak gender balance.

The Centre should ensure that its scientific advisory board is gender-balanced.

In a comment to the report, CASA Centre director Magnus Langseth pointed out that this is a challenge. It is not only a challenge for CASA, but the whole field of research nationally as well as internationally.

«We have made considerable efforts to attract more female researchers, and we will continue to do so. The challenge is that the number of females in our field is low. We cannot conjure them up», Langseth stated.

Research that improves competitiveness

The panel of four international experts concluded that CASA performs excellent research. The Centre has met its overall objective «to provide a technology research platform based on multiscale testing, modelling and simulation for the development of smart, cost-effective, safe and environmentally friendly structures and products». One of the outlines is that the research will improve the competitiveness of its 14 industrial partners.

Other statements:

- The Centre has an impressive working capacity covering many fields of mechanics involved in safety and security.
- The Centre has a distinct research profile, and its activity is geared to produce research outputs, both on the short term and long term.
- The level of scientific quality is very high and recognized worldwide.
- SFI CASA´s researchers have high international reputations and visibility.
- The Centre has a well-running organization for research training.
- The PhD students are co-located in the Centre's premises and feel well supported by the Centre's staff and partners.
- There is an open atmosphere in the Centre, and the supervisors are available for guiding the research students most of the time.
- The PhD candidates have had many opportunities to produce publications with their supervisors and each other.

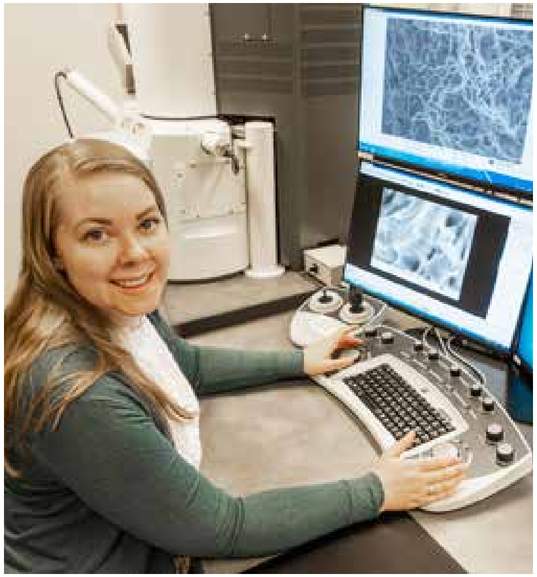
Commendable process

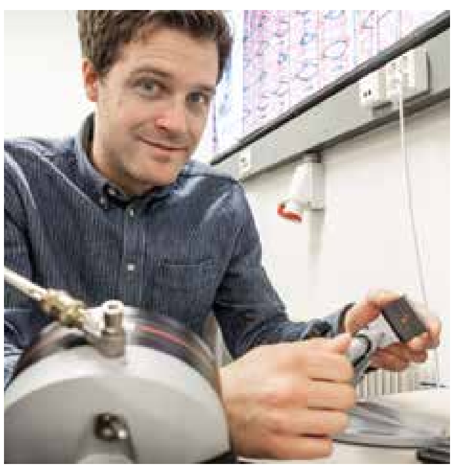
The evaluation outlines that CASA is well organized and governed with appropriate support from the host institution, NTNU.

In total, the evaluation team finds that the Centre's 14 partners constitute a well-structured critical mass sharing generic needs for validated computational tools.

Also, the team concluded that the process and pathway from basic research to knowledge transfer for the partners is commendable. They also find it commendable that industry has made an effort to articulate its needs to the multidisciplinary research community – 3 departments at NTNU and SINTEF Industry.

MEET THE DOCTORS





Unravelling the CHAOS in the Interior of Polymers

Due to the attractive combination of low weight and high strength, fibre-reinforced plastic components are often used in car bumpers, wind turbines and sports equipment.

Every industry which moulds fibre-reinforced thermoplastics for withstanding extreme loads should take an interest in Petter Holmström's PhD work. His objective is increasing our understanding of the ability of the material to withstand extreme loads. Fibre-reinforced thermoplastics can replace metals, and it is the glass fibres that make the material stronger. Thus, the industry can reduce the weight of cars or other constructions while still retaining the required stiffness and strength.

The short fibres look like tiny little sticks. They measure 0.1 to 1 millimetre in length and about 15 millionth of a metre in diameter. Control is crucial when moulding them. The more you can control their behaviour, the stronger the plastic you produce, according to Holmström.

Another benefit of moulded thermoplastics is that a single component can replace part of the structure that was traditionally composed of many parts assembled together. This is especially important for the automotive industry where it is vital to reduce weight, time consumption and costs.

IF YOU CAN´T SIMULATE IT – YOU CAN´T USE IT

When fibres are moulded into a thermoplastic, the material becomes stiffer, stronger and more brittle. It is injected just like a heated liquid into moulds. Then it cools and hardens to the shape of the mould to form highly complex geometric components.

According to Holmström, the industry has not paid a lot of attention to the fact that glass-fibre reinforced thermoplastics can have different properties in different directions. Tension tests show that the material can be twice as stiff and strong in the longitudinal direction as in the lateral direction. «When we know there is a factor of 2 that depends on the load direction,the industry should account for it», he says.

When a plastic component is designed to carry loads in interaction with other parts, you have to be able to simulate how it reacts to external loads. The behaviour of the material must be described mathematically in a material model. «If you can't simulate it, you simply cannot use the material – unless we are talking about kitchen utensils», according to Holmström.

LIKE LOGS IN A STREAMING RIVER

When injecting hot liquid thermoplastics into a mould, the orientation of each glass fibre is decided by the flow conditions. It is just like a river for floating logs. The speed of the stock timber, the current´s strength, and the direction of the water are determined by depth, stones or other obstacles. When there are many obstacles, the logs can easily jam together and become blocked.

In a simple, flat panel that is 3 millimetres thick, there will be few obstacles, and the fibres will spread out fairly uniformly.

In a complex component, like a car bumper, it is different. There will be nooks and corners that hinder the streaming flow of plastic. Thus, just like the logs, the fibres can lump together and concentrate in certain areas.

A MODEL THAT COMPUTES BEHAVIOUR

Holmström has made extensive use of X-ray microscopy to study the interior of the materials. The X-ray images show myriads of these tiny little sticks spread in what appears to be chaos. Holmström unravelled this chaos. He compiled statistics on the distribution, direction and the angles in which the fibres lie. He says that this is essential knowledge. The material´s ability to withstand loads is determined by the orientation of the fibres in the moulded component.

AVOID THE WEAK ZONES

The orientation of the fibres depends on the injection process. At the same time, the mechanical properties of the component depend on their direction. This is a considerable challenge for the industry.

To optimize the design process, one must first simulate the injection process. Then, the information about the fibre orientations is transferred to strength simulations. «This is possible to do today, but industry has not started to use such methods», according to Holmstrøm. As a result, it is difficult to know beforehand whether a product has an unfavourable fibre distribution. «It is the totality that matters. The weakest zone will collapse. When you design something that should withstand extreme loads. It is all about avoiding the weak zones».

USEFUL FOR THE AUTOMOTIVE INDUSTRY

For the automotive industry, it is crucial to utilize the fact that fibre-reinforced polymers are less stiff and weaker than steel. Thus, in a car crash, the energy will be absorbed by the polymer car bumper instead of the metal parts or the body of a pedestrian.

The more the force can spread, the less damage is done to a person who is hit by the vehicle. This demonstrates the advantages of thermoplastics. And all of it can be simulated, as long as we have access to good models that represent the fibre-reinforced component.

This will help the industry to save both time and a lot of money.

PETTER HENRIK HOLMSTRÖM

Defence: 28 March 2019

Thesis: «An experimental and numerical study of the mechanical behaviour of short glass-fibre reinforced thermoplastics.»

Supervisors: Professors Arild Holm Clausen and Odd Sture Hopperstad

EMIL CHRISTIANSEN

Defence: 27 September 2019

Thesis: «Nanoscale Characterisation of Deformed Aluminium Alloys»

Supervisors: Professor Randi Holmestad, Senior Research Scientist Calin Daniel Marioara and Professor Odd Sture Hopperstad

Rocking Around at the NANOSCALE

«You have to go down there to see what really happens. It is like a reality-check on the theories. In a way, the answer book lies at the nanoscale».

Emil Christiansen knows more than most about what happens deep inside aluminium when the material is bent and pulled to fracture. He works with nanoscale characterization in SFI CASA´s Lower Scale Programme.
«We try to understand how the smallest building blocks behave, when we bend, stretch and deform the material. This is simply because this knowledge will give us structural materials of higher quality», Christiansen says.

WHO IS IT GOOD FOR; AND WHY?

If you think of CASA´s Virtual Laboratory as a modelling chain for the design of aluminium structures, his work fills the absolute starting point. When working on his PhD thesis, he merged three fields of expertise: Materials physics, metallurgy and materials mechanics.
According to Christiansen, producers of aluminium must know what affects the properties of their alloys to develop and design new and improved compositions. Car manufacturers must be able to model their products to limit prototype tests. Besides, to be able to predict and prevent failure, the oil and gas-, and construction industries must understand the limitations and behaviour of applied materials.

THE POWERFUL TEM

«If we aim to make models that are reliable and based on physics, we have to go down to this scale. What happens on this level, determines how the material behaves when it deforms under strain», he says.
It takes the most powerful tool to study what happens at this level. Transmission Electron Microscopy (TEM) enables researchers to zoom in on precipitates with a length of one thousand of the breadth of a human hair.
The TEM is one of the world's most sophisticated microscopes, and it works with the help of a beam of high energy electrons shot through a thin specimen. As they pass through, the electrons interact with the sample and give detailed information about the materials.

LIKE REINFORCEMENT BARS IN CONCRETE

Pure aluminium is a soft, easily bendable material. When aluminium is bent, stretched and distorted, the atoms are rocked around. These intriguing motions can be observed by the TEM.
Most metals are made up of crystals or grains where the atoms are incredibly well-organized and lie beautifully and neatly ordered in grids. Tiny amounts of magnesium or silicon can be added to strengthen aluminium. This is the stuff that forms the precipitates. These small particles are shaped like needles and act like reinforcement bars in concrete.

PRECIPITATES ARE KEY

The precipitates are vital factors. According to Christiansen, physicists love them because of their significant influence. The temperature during processing is critical, it decides the precipitates that harden the metal and contribute to its strength. To give an idea of their size: several billion would fit onto a lump of sugar.
When aluminium is put under strain or pressure, the neatly stacked atoms will move with the help of a particular type of grid defect.
«We call these defects dislocations, tiny shifts of all the atoms along a line within the crystal. If a noticeable deformation should occur, many of these types of dislocations have to glide from one side of the crystal to another», Emil Christiansen explains.
The strength of a metal is determined by how easily the dislocations can be moved around.

INVADED BY NEIGHBOUR ATOMS

The atoms that rule this universe of incomprehensible tiny detail seem quite humane in their behaviour. Each atom has its own sphere surrounded by a certain number of atoms laid out in a stringent structure. So, when the material is exposed to load or pressure, these atoms are pushed closer into another atom´s intimate sphere. And they hate it. Naturally, it is like being invaded by troublesome neighbours from all sides. At a certain point, they have had enough. The moment when the invaders come too close is when the pressure or impact on the material becomes too strong. Then the atoms will give in, move away or dislocate. This is the moment where the material starts to deform.

PREDICT STRENGTH AND FAILURE

It is fascinating to observe, and absolutely possible to model material behaviour at the nanoscale. However, it is hard to say how relevant this would be for full-scale aluminium production. It would take tremendous amounts of computing power to model materials at this scale. Christiansen admits that it is demanding to put what you learn on a lower scale to use at a more substantial level.
«We have seen that in CASA too. But this knowledge could work as a kind of a compass or a guide towards improving today´s alloys and models».

Digging DEEP for Damage and Failure

Bjørn Håkon Frodal provides us with new knowledge about how to predict the behaviour of elements that are invisible to the naked eye.

Four years ago, Bjørn Håkon Frodal delved into the microstructures of aluminium alloys. His mission was to predict the behaviour of elements that are impossible to see with the naked eye. To most of us, this would be a mission impossible. All the more reason to send a loving thought to researchers like Bjørn Håkon Frodal, who embark on journeys into the universe of metallic materials with their grains, particles and atoms. Their motivation is to understand and predict the behaviour of these tiny, invisible inhabitants. And as a matter of fact, this is life-saving research.

FUNDAMENTAL UNDERSTANDING MAKES US SAFER

«We must improve our understanding of what happens deep down inside when the materials are subjected to strains in compression and tension. Understanding the physical mechanisms at the microscopic scale and the role of the microstructure in metallic materials is fundamental», according to Frodal. This is because the more we know, the safer the industry can create alloys that will make cars, ships, pipelines, buildings and other structures safer.

Frodal's work is a substantial step forward when it comes to a understanding and describing the ductile fracture process of aluminium alloys. This is a type of fracture marked by extensive deformations, where the material is pulled apart instead of shattering. His thesis is a comprehensive study that consists of experimental and numerical studies. It is based on around 200 experiments on 3 different extruded aluminium alloys heat-treated to 3 different conditions.

TORTURING MATERIALS

The tests are comparable to extensive torture. First, the specimens go through extreme levels of compression. Then, they are continuously pulled to fracture in tension.

Why? Because in the real world, this is what happens, for instance, when a car collides. Bjørn Håkon Frodal tells us to imagine the crash box that lies behind the bumper beams in our vehicle. It is made of aluminium, and its task is to absorb energy and protect our fragile human bodies. During impact, the material will first be compressed and fold. After, there is a tension stage. He is motivated by investigating the kind of influence compression loading has on the damage evolution and ductile failure process in this tension stage.

To find out, he digs deep into the interior of this silvery-white, soft, light and ductile metal. It has a granular structure, and each grain measures 50-100 micrometre (0.05-0.1 mm).

Inside the grains, there are stacks of extremely well-organized atoms: They lie neatly in grids, all with the same spatial orientations. There are also precipitates, particles shaped like needles or disks that consist of magnesium and silicon. The temperature during processing is critical. Still, those precipitates are the guys that harden the metal and contributes to its strength.

IRON-MEN THAT COLLAPSE

«The deeper we go down in scale, the more information we get. But my foremost interest is at the level of crystals and primary particles. Because it is here that damage and failure occur», Frodal says. Actually, he has contributed to a crystal plasticity model, that makes it possible to predict what goes on inside each of those tiny little grains when the material is loaded. As they consist of iron and silicon, primary particles are hard. When the material deforms, they crack and nucleate voids.

As the strain increases, the voids grow and will eventually merge with other growing voids. When this happens, the material fractures.

One of Frodal´s achievements is the implementation of a crystal plasticity model in SFI CASA´s Virtual laboratory (VL) for the design of aluminium structures. You can think of the VL as a modelling chain, with four main ingredients starting with nanostructure modelling. The next level is Bjørn Håkon Frodal's home turf, the crystal plasticity modelling. Then come unit cell modelling and localization analysis. The latter is used to establish a failure criterion for the alloy.

IMPROVING THE VL´S MODELLING CHAIN

According to his supervisor, Professor Odd Sture Hopperstad, Frodal's research has strengthened the modelling chain and improved the VL as a tool for the design of cars and protective structures. It enables researchers to perform a greater variety of robust and faster simulations. His work represents a significant step towards SIMLab's long-term objective: using the virtual lab to minimize or even make physical testing unnecessary in the design of structures.

He reveals that his happiest working moments occur when he runs finite element-model stuff. When the curves that appear on his screen fit nice and precisely with the physical tests. Those are the moments of truth when models and simulations correspond with what happens in reality.

«I enjoy going to work every day. I appreciate the feeling of having the time to immerse myself in these questions. There is always this feeling that we need to explore more. Nothing is fulfilled or perfect. New issues pop up all the way».

BJØRN HÅKON FRODAL

Defence: 8 October 2019

Thesis: «Micromechanical modelling of ductile fracture in aluminium alloys»

Supervisors: Professors Odd Sture Hopperstad and Tore Børvik

CHRISTIAN OEN PAULSEN

Defence: 21 October 2019

Thesis: «Experimental characterization of two-phase steels»

Supervisors: Associate professor Ida Westermann and Professor Tore Børvik

Spitting GOLD to STRENGTHEN Steels

Christian Oen Paulsen went by way of gold to bring our understanding of steel one step further.

When you are searching for local strains in the microstructures of steel in a scanning electron microscope (SEM), contrast is essential. That is where the gold comes in. This is because sputtering a layer of the precious metal on the surface of a steel specimen improves the contrast and resolution by one hundred times compared to spray painting.

The experimental technique of gold sputtering plays a central role in Christian Oen Paulsen´s work on micromechanical modelling of steel.

A GOLDEN RECIPE

In 2017, he spent one month at the University of Manchester. This is where he learnt the technique that helps him to see and measure the deformation and damaging mechanisms of different steels.

«The research community in Manchester was accommodating and shared their knowledge, tips and tricks with us. Thanks to them, I returned to NTNU with a recipe that we could use on steel».

The challenge of the technique is to get the gold layer to form particles that enable us to see what happens. In the aftermath of his stay in Britain, Christian Oen Paulsen has developed the Manchester method further.

CHALLENGE: FROM LAYER TO PARTICLES

He has performed more than 100 tests with 6 different qualities of steel. It has been time-consuming work. Each specimen is polished to a mirror-like surface before being coated with a continuous layer of gold in the Gold Sputter Coater. The next step is to remodel the layer into particles by placing the specimen on a hot plate.

For stainless steels, the specimens are exposed to water vapour at 300 degrees Celsius for one hour. This will decompound the gold layer and form particles. This is the simplest and fastest method. But for other types of steel, this vapour process will cause corrosion.

CHASING FOR CONTRAST

There is another way, too, to transform the gold layer to gold particles. Here, the specimen is kept at 180 degrees Celsius in an 02-free chamber for 96 hours with a mixture of argon and styrene flowing across the surface.

«Different materials require different techniques», Oen Paulsen says.

Part of his research is comparing what you actually see in the SEM when various types of steel specimens have been exposed to different techniques. Some methods do not provide sufficient contrast for digital image correlation. Other methods, such as the gold remodelling method, provide a finely dispersed gold speckle pattern on the surface, giving excellent contrast.

IMPROVES OUR UNDERSTANDING

He has studied different qualities of steel at the micrometre level. Representative areas of the patterned specimen were recorded by an in situ SEM tensile test. SEMs are designed to make images of the surfaces of tiny objects. In situ means that the microscope is used to watch and collect data in real-time.

Oen Paulsen explains: «The microscope fires a beam of electrons onto the specimen which bounces back with an intensity based on the atomic weight. Alternatively, you can capture signals with an intensity based on the surface topography. This is completely different from a transmission electron microscope where the beam of electrons goes right through the sample».

He combines tensile testing with digital image correlation (DIC). DIC is an optical technique for measuring strain and displacement where digital photographs of a component or test piece are compared at different stages of deformation. By tracking blocks of pixels, the system can measure surface displacement and build full-field 2D and 3D deformation vector fields and strain maps. The result is a strain map with a spatial resolution capable of resolving strains at a sub-grain level.

HELP THE DESIGN OF BETTER STEEL

Oen Paulsen's goal is to link the behaviour in the microstructure of different steels with the global performance of the material, thus helping to design better steel. Combining SEM and DIC, the PhD candidate and his gold particles have paved the way for studying how steels behave under strain at a lower scale than was possible before.

And we *are* talking small.

He is looking at particles, cracks, fractures and patterns down to the sub-micrometre level – less than 0.001 millimetres, that is.

His supervisor, Associate Professor Ida Westermann, declares that Christian Oen Paulsen has improved the understanding of the initiation of deformation in the steel. This leads to better analyses of materials and structures, and it is a step forward for CASA´s material models.

A JOINT EFFORT

«The starting point was the sputtering technique from Manchester. When combining my work with CASA-researcher Egil Fagerholt`s DIC software eCorr, and SINTEF Research Scientist Afaf Saai´s Finite Element simulations, this is starting to become very interesting», Christian Oen Paulsen says.

He adds:

DIC functions like an answer book. Our joint effort enables us to improve and verify the numerical models. It took a lot of time and effort to bring us here. Hopefully, this can be investigated further».

Bright **GLASS** Comes with a Shady Side

Our craving for daylight has accelerated the use of glass in modern constructions. However, for those concerned about safety, our passion for the light comes with a dark side.

SFI CASA´s Karoline Osnes is one of those people. She knows more than most of us about how glass behaves under an extreme impact.

«Glass is becoming more and more of stand-alone building material. The use of it has advanced from simple windows to full façade claddings and load-bearing components. Still, our knowledge about its ability to withstand extreme loads has not kept pace with these trends», she says.

THE BIGGEST THREAT

In years to come, we can expect more severe weather events. Also, the risks of sabotage and terror attacks are expected to continue. When the unthinkable happens, we must be as well protected as possible - whether we sit in our car, in a railway carriage or in an office building.

As the use of glass increases, it still remains the weakest point in a building. This means less protection for vulnerable human bodies. During an explosion, glass, concrete, aluminium or steel can transform into thousands of potentially deadly fragments. In the event of an urban explosion, 80 per cent of the suffered injuries is caused by pieces of glass that are forcefully scattered around.

NEED FOR MODELS THAT PREDICT BEHAVIOUR

Thus, carefully chosen glass solutions are essential. A common approach to reducing this threat is using laminated window glass, where two or more plates of monolithic glass are bonded together by a polymeric interlayer. When the glass breaks, the polymer keeps the dangerous fragments in place.

According to Karoline Osnes, there is an obvious need to develop models and methods that can predict the response before, during and after glass fracture.

WHERE, WHEN, WHY AND HOW DOES GLASS BREAK?

She has subjected more than 100 panes of glass to blast loads and ballistic impacts. The experiments were performed in the Shock Tube and the Gas Gun at SIMLab, NTNU.

Her aim is to describe the characteristics of the two types of glass as precisely as possible. Thus, it will be possible to calculate which strength a specific kind of glass should have to act as a protective element.

What happens in a laminated glass after the glass breaks, depends on where and when the fracture starts. There are several other factors too:

It is not only the type of glass, it is also the different polymers, the production process, moisture, temperature, the water quality used when cleaning. And, of course, the speed of the impact. «It is fairly complicated to simulate this. However, we have managed to develop some tools that describe what happens», Karoline Osnes says.

PIONEER WORK AND UNPREDICTABLE FLAWS

Her research is pioneering work. Few experiments have been performed before to lure the secrets out of this attractive, yet unpredictable material. The unpredictability lies in the micro-cracks or flaws in the glass. They measure a maximum of 0.1 millimetres. Osnes assumes that there are a certain number of flaws and that their size and orientation vary. When glass breaks, the starting point is always in these flaws. But even if two panes of glass seem identical, the microcracks will not be precisely the same. Thus, the glass will behave differently in each blast, although the impact is the same.

It is a challenge to conduct the experiments and simulate what happens. However, Osnes takes the variation of the fracture behaviour into account and has produced a model that describes the trends seen in her tests.

RESEARCH PUT TO USE BY CAR MANUFACTURERS

She says that the industry notices that the strength of glass varies and that they are interested in models that can describe this variation.

The new knowledge will make a difference for industry, whether they produce cars, simple windows or full facades. With the terror attack in Norway on 22 July 2011 as a backdrop, her work is relevant for the planning of the new government administration complex in Oslo. Also, partner of CASA, car manufacturer BMW, has already put her model to use in their standard roof strength test.

THE ACTIVITY IS GROWING

Due to the relative novelty of glass as research material, there is only a limited amount of literature and experimental data to study. However, the activity is growing. More and more impact studies on glass are coming, according to Osnes.

SFI CASA´s predecessor, SIMLab, directed attention towards anti-terror just months before the 2011 attack in Oslo. The Ministry of Local Government and Modernisation joined the Centre as partners because they needed to be confident that the objects they were going to build can handle an impact. Besides, they wanted the capacity to simulate with a high level of precision how impact affects whole structures, what fragments do to them, and how resilient they are.

Now, Karoline Osnes contributes to more predictive glass design.

«Hopefully, these tools can lead to safer and better glass solutions», she says.

Karoline Osnes

Defence: 7 November 2019

Thesis: «Monolithic and laminated glass under extreme loading: Experiments, modelling and simulations»

Supervisors: Professors Tore Børvik and Odd Sture Hopperstad

Susanne Thomesen

Defence: 14 November 2019

Thesis: «Plastic flow and fracture of isotropic and anisotropic 6000-series aluminium alloys: experiments and numerical simulations»

Supervisors: Professors Odd Sture Hopperstad and Tore Børvik

The Provider of INSIDE Information

An extensive series of experiments enabled Susanne Thomesen to uncover the secrets of aluminium. The inside information fills part of the big picture under construction in FractAl, a Toppforsk project.

Susanne Thomesen is the first of five PhD candidates in FractAl to defend her thesis. She has investigated the microstructures and what happens inside aluminium alloys when subjected to severe loading conditions.

«I explore the basics. Knowledge about the smallest parts that help us to explain how the material behaves under large deformations and fracture», she states.

HOW TO MODEL ALUMINIUM THAT BREAKS

The 5-year Toppforsk project FractAl started in 2016. The full name of the project is Microstructure-based Modelling of Ductile Fracture in Aluminium Alloys. It is a concurrent project to CASA, which reaps benefits from the research. Where CASA focuses on structural analysis of steel, aluminium, polymers and glass, FractAl-researchers like Susanne Thomesen makes a concerted effort in a specific area. They understand more than most about what happens when aluminium fractures. They search and explore the properties of different alloys down to the nano-level and how the atoms react to different kinds of deformation. They aim to build a multiscale modelling framework that provides a fundamental understanding of ductile fracture in the material.

A NEW WAY TO DESIGN ALUMINIUM STRUCTURES

Thus, they will pave the way for an entirely new way to design aluminium structures. Hopefully, the new framework will enable designers and engineers to select the most suitable alloy for a given structure. In the future, this will also reduce the need for time-consuming and costly mechanical tests.

«Think of a carmaker that runs several hundred crashes on car prototypes every year. If you could simulate some of those crashes instead, it would both help to protect the environment and the industry of large sums of money and a lot of time», Thomesen states.

STRONG FORCE, SLOW SPEED, LACK OF ACTION

She subjects her tiny specimens to a combination of slow speed and tension. She tends to excuse the lack of action in her tests, compared to colleagues who subject concrete or glass to blast loadings or maltreat aluminium. In her experiments, it takes about fifteen minutes before anything exciting happens, that is, when the specimens give way and fracture. During loading, she uses different techniques to measure the deformation of the samples. This work involves the use of extensometers, laser-based measuring, digital image correlation (DIC) and edge tracing techniques.

CLIMATE-FRIENDLY, SAFE AND GREEN

Thomesen explains: «The distribution of grains and particles, their size and their orientation to one another. All this matters when you want to understand the behaviour of the material subjected to large deformations».

Of course, now and then, people ask her, what is the greater good in her research. She states: «I am not doing anything that makes everyday life easier for you or me in the kitchen or elsewhere at home. But I like to think that I contribute to the bigger picture. This research saves resources. It helps more climate-friendly production. Safer constructions, greener cars and the like».

Susanne Thomesen has studied three different aluminium alloys under various loads. These are the alloys that are most commonly used in protective car components such as crash boxes and bumpers. During a collision, these are the parts of a car that absorb the most energy. Her work includes hundreds of experiments and simulations.

SUPPLIER OF FRACTALS DATABASE

«I enjoy doing tests and the satisfaction that comes when my expectations are fulfilled, and I find the answers. I am not the kind of person that mainly sits and solves long equations. I thrive by putting theory into practice». She describes her work as a supportive activity. FractAl has established an extensive database for ductile fracture of different types of aluminium alloys. Thomesen's thorough descriptions of the microstructures will supply the base and be implemented into FractAl´s microstructure-based modelling sequence. «The idea is that the information from this level can be transferred and the models validated on larger scales».

ONE PIECE IN A BIG PUZZLE

Thomesen shows some of the tiny specimens she has used in her PhD work. Now they are broken and maltreated, stored in transparent and carefully marked plastic bags. She has spent countless hours zooming in on their fracture surface and the microstructure in the surrounding material. «The experiments and the characterization I have done can now be used by other researchers. My studies have contributed with data that are useful in the further development of the framework. And hopefully, the models involved can be improved. My work is one piece in this puzzle, and I feel that what we do is important». After her doctoral defence, she signed up as a post-doc in SFI CASA. «I appreciate being part of this group. We help each other, and I feel that we all join forces and pull in the same direction. People enjoy being here, and I enjoy being part of it».

Simulations Getting Closer to an **ACTUAL** Vehicle Crash

The body of a modern car is like a gigantic 3D puzzle, with a multitude of different materials, parts and pieces. The joining of all these mixed parts is a crucial challenge when designing car bodies.

The automotive industry is out on a never-ending hunt to reduce time, weight and cost in vehicle development. At the same time, complexity is increasing.
«Virtual testing is an important tool in solving this conflict of interest», states Matthias Reil.
These challenges are also the motivation behind his PhD work, carried out at SFI CASA and the Department of Structural Engineering, NTNU.
In the development of a passenger car, numerical methods apply to design the car body.
«Numerical simulations substitute costly and time-consuming real-world tests. However, to develop and calibrate the numerical models, we need to have an accurate understanding of all the applied materials and joining technologies», Matthias Reil states.

HOW TO MODEL A HYBRID CONNECTION IN A CRASH SIMULATION

Just a few decades ago, car bodies consisted primarily of steel parts joined by welding. The joining of today´s dissimilar materials is very challenging. Welding is often not an option.
Matthias Reil focuses on numerical models to describe the behaviour of adhesively bonded self-piercing riveting connections between steel and aluminium. This is a common method in modern car bodies.
«My objective was to develop an efficient and reliable way of modelling such a hybrid connection in a vehicle crash simulation», he explains.
Reil wrote his master's thesis at BMW on the structural analysis of carbon fibre reinforced plastic materials. At that time, BMW was already a partner of SFI CASA. When he had finished his thesis, BMW offered him a position as a PhD candidate.

MOTIVATED BY THE INDUSTRY´S NEED FOR RESEARCH

Reil spent 18 months in Trondheim on his PhD and thrived on the variety between Germany and Norway. «Doing the PhD as part of SFI CASA came almost naturally as it offered great benefits for all parties. For me as a PhD candidate, this meant access to excellent supervision, cutting edge test facilities and especially the possibility to do research abroad», he says.
At BMW, he worked in a large R&D Facility with thousands of engineers & other developers. At SFI CASA there are fewer people and smaller offices. This gave the space needed for really digging deep into the scientific aspects of the thesis.
For BMW, having a shared PhD candidate, meant having someone at the heart of the research project, enabling valuable information flow to the company. According to Reil, SFI CASA was given useful direct input regarding the needs of industry and industrial implementation.

SAFE, RELIABLE AND COMPETITIVE CARS

Matthias Reil underlines our need for a deep understanding of the mechanical behaviour of all the materials and joining technologies applied in the car body. Without this understanding, we would not be able to design safe, reliable and competitive cars.
«Having an accurate numerical representation of adhesively bonded self-piercing riveting connections is an important piece of the puzzle».
He says that the macroscopic models describe the mechanical connection behaviour with reasonable accuracy and cost. Therefore, they can apply in full-scale crash simulations.
The motivation behind his PhD work came both from BMW and SFI CASA. BMW car bodies use self-piercing riveting and adhesive bonding. They join a great variety of materials and thickness combinations. To establish the mechanical behaviour of these connections through testing is very expensive. Also, it requires a lot of time. «Substituting the experimental characterization by a virtual approach was therefore especially important for BMW», Matthias Reil says.

RESEARCH THAT MAKES A DIFFERENCE

The automotive industry aims to halve the number of physical crash tests. CASA will contribute to this through its Virtual Lab. Reil describes CASA as a player at the forefront of virtual testing. He says that the applied virtual approaches, both for materials and joints, show promising results. «I am convinced they will contribute to reducing cost and time in the vehicle development».
Reil's doctoral research presents a brand-new test setup for adhesively bonded and point-wise connected components. He explains: «With a test on the component level you want to validate your numerical models under conditions as close as possible to an actual vehicle crash. That is, with reduced effort and precise control of the boundary conditions and loadings. The new component test enables us to do precisely that. It can be performed under quasi-static and dynamic conditions and allows us to control the loading in the connections precisely. Furthermore, we can identify the exact moment and the sequence when failure takes place».

He is convinced that his research will contribute to safer and lighter car bodies. «However, modern passenger cars are highly optimized and very complex products. The sum of the work performed by all researchers and engineers is what makes the big difference».

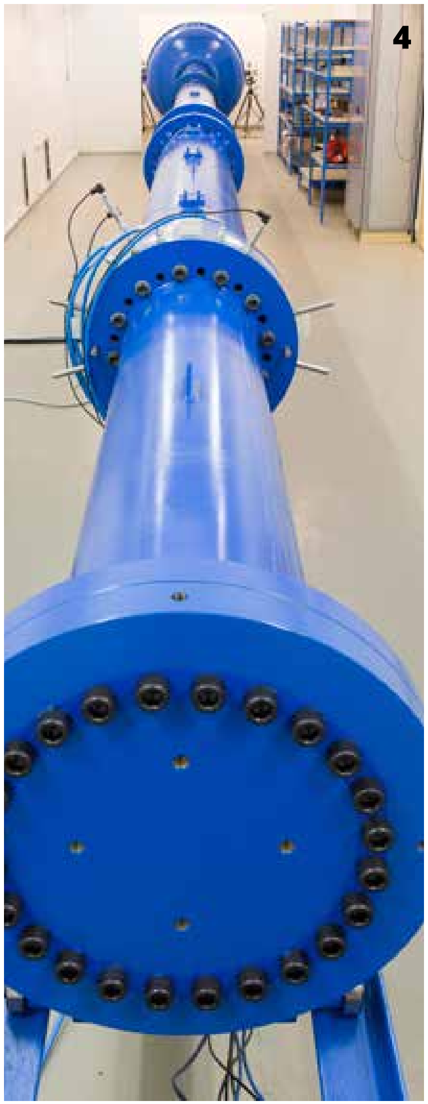
MATTHIAS REIL

Defence: 21 November 2019

Thesis: «Connections between steel and aluminium using adhesive bonding combined with self-piercing riveting: Testing, modelling and analysis.»

Supervisors: Associate Professor David Morin, Professor Magnus Langseth and Dr. Octavian Knoll, BMW

TEST FACILITIES



SFI CASA has access to test facilities in several laboratories at NTNU and SINTEF. Below is a list of the most important testing equipment. In addition, a number of uniaxial test machines are available.

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 carried out at low and high temperatures. The mass of the projectile ranges between 2 and 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.

Shock tube facility (4)

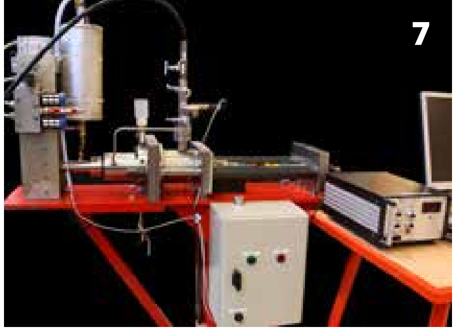
The tube is 18.2 m long and is divided into six sections. The tube ends in a 5.1 m^3 dump tank. The tube starts with a circular internal cross-section with a diameter of 0.34 m before it is transformed to a square cross-section of 0.3 m × 0.3 m. Threaded holes in the tube floor enable mounting of test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

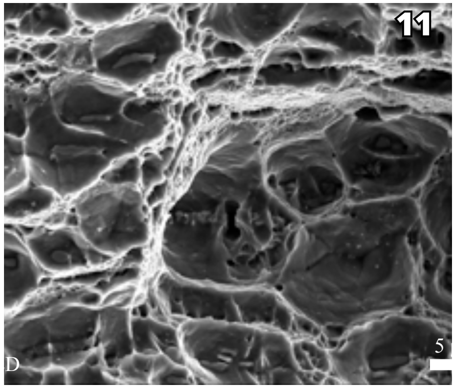
Split-Hopkinson pressure bar (SHPB) (5)

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 a 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 combined with internal pressure.





(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

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. Maximum energy delivered to the trolley is approximately 500 kJ. At present the mass of the trolley is in the range between 800 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. An induction heater facilitates tests at elevated temperatures, and a cooling chamber provides low temperatures.

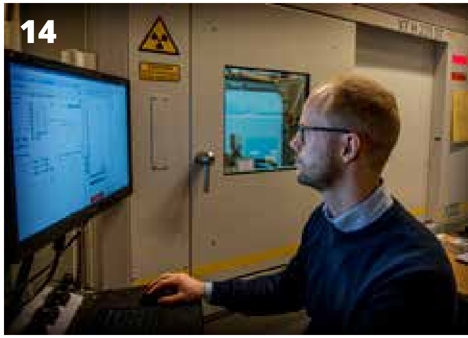
Cameras (10)
Impact testing of materials and structures are recorded using high-speed cameras. The Kirana-05M camera has a maximum frame rate of 5 000 000 per second (FPS) allowing detailed studies of crack propagation. The research group has 4 more high speed cameras and several cameras for Digital Image Correlation measurements. They also have an infrared camera for temperature 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).
3 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 5 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.

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 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-meter, 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.



VISIBILITY

Media strategy

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 this respect, 2019 has been a good year. We have had a great deal of publicity on different media platforms.
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. We continued this work in 2019.

Newsletters

We gave SFI CASA's newspage (sfi-casa.no) a makeover in 2019. In all, ten newsletters were distributed to partners, contacts and other people in SFI CASA's social and professional network. The content is both research news and in-depth interviews with key personnel working with or connected to SFI CASA. Full versions of the articles on the 7 PhD candidates in this annual report were published here throughout the year. A new Technical Newsletter intended solely for the partners in SFI CASA was also started in 2019. In total, we distributed five editions.

Presentation video

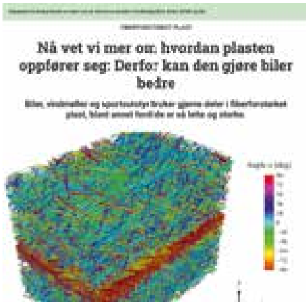
Our new, animated presentation video premiered in November. In 90 seconds, the video captures how much of CASA's research focuses on improving physical security. Hopefully, the animation serves as a quick, visual and straightforward introduction to explain the research of the Centre. The video was made by Rastlaus Media AS.
In addition, the CASA video that premiered in January 2017 continues to be an effective presentation tool, illustrating how CASA contributes to research that benefits society as a whole.

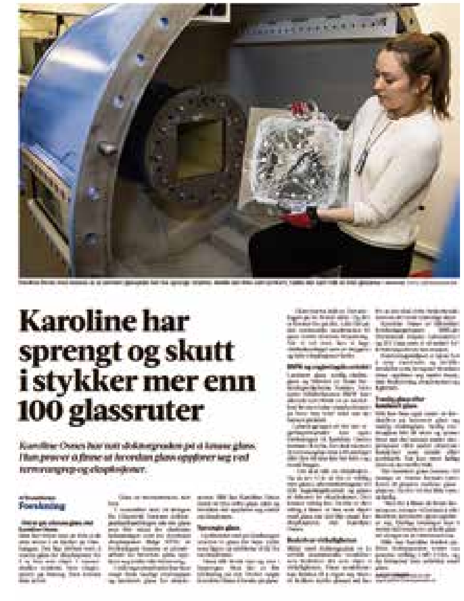
Social media

The excellent collaboration with NTNU's communication division continued in 2019. NTNU's Facebook page Science and Technology shared several of the stories published on sfi-casa.no. Also, reports from traditional media were re-posted and shared here. In addition, the university's blog about technology and natural sciences, NTNU TechZone, published our stories. When it comes to Twitter, we mainly shared news, videos and stories through the university's official account @NTNU, which has over 36 000 followers.
Our digital Christmas greeting for 2019 had more than 6200 views on Facebook.

CASA in the media

January: National Public Radio (NPR) presented a story on the Ferry-free E39 project. Under the title «Norway Embarks On Its Most Ambitious Transport Project Yet», Associate Professor Vegard Aune and PhD candidate Henrik Granum were interviewed.
Also, CNN.com published an article on the project: «Can Norway win the global race to build a 'floating tunnel'»? Researcher Martin Kristoffersen contributed to the story that was later republished in the Norwegian online paper Nettavisen.





March: Petter Holmström's PhD thesis on Fibre-reinforced Polymers caught interest. The research magazine Gemini published an article on his extensive work. Teknisk Ukeblad republished the story and distributed it through their newsletter, which has 92 000 subscribers. Another site, plastforum.no that covers this business sector, also presented the story of Holmström's work.

July: Centre Director Magnus Langseth published the chronicle «How to Link Knowledge and Commerce?» in Norway´s leading business paper Dagens Næringsliv. The chronicle was republished in the online newspapers Khrono and Universitetsavisa.

September: The Midway Evaluation gave SFI CASA excellent remarks. The University Paper at NTNU published two articles on the report. The fact that PhD candidate Karoline Osnes knows more than most about how glass behaves under an extreme impact caught the interest of the media. The regional newspaper Adresseavisen published a story on her work.

October: PhD Candidates Bjørn Håkon Frodal and Emil Christiansen featured in the research magazine Gemini and «ABC Nyheter». Karoline Osnes made frontpage news in Sunnmørsposten with her pioneering work on glass.

November: Norwegian SciTech News, the international site for research news from NTNU and SINTEF, published the story «Breaking glass to make it safer». Vikebladet Vestposten also brought a short story from the defence of Osnes´ doctoral thesis.

Guest lectures at SFI CASA

- Franck Lauro, Université Polytechnique Hauts-de-France, France. Characterization and modelling of adhesives for crash/impact. 27 March 2019
- Vincent Faucher, French Alternative Energies and Atomic Energy Commission (CEA), Cadarache, France. Fluid-structure interaction with interfaces and discontinuities. 25 April 2019
- Rafael Sancho, Universidad Politecnica de Madrid, Spain. 10 May 2019
- Alessandro Rossini, PWC AS. How to Bridge the Technological Valley of Death? 6 June 2019.
- Arjan Strating, Audi AG. New challenges in safety engineering of electric cars. 24 June 2019.
- Rene Kaufmann, University of Southampton, UK. Full-Field Surface Pressure Reconstruction Using Deflectometry and the Virtual Fields Method. 15 August 2019.
- Cihan Tekoglu, TOBB University of Economics and Technology, Turkey. Effect of Damage-Related Microstructural Parameters on Crack Surface Morphology in Ductile Metal Plates. 7 October 2019.
- Knut Rakvåg and Johan Kolstø Sønstabø, Multiconsult. Plastic analysis in engineering. Protective structures subjected to extreme loadings. Lecture in the course Steel Structures 1. 14 October 2019.
- Norman Fleck, University of Cambridge, UK. Microarchitectured materials: currect status and future outlook. 16 October 2019.

Guests from industrial partners

- Christophe Grolleron and Cedric Bouton, Renault. 26-27 March 2019.
- Oda Toreskås and Sumita Dey, Norwegian Defence Estates Agency, 3-5 April 2019.
- Lukas Schulenberg and Christian Beck, Audi AG. 20-24 May 2019.
- Karin Lingborg, Hydro Extruded Solutions, Sweden. 23 May 2019.
- Arjan Strating, Audi AG. 24-27 June 2019.

PhD defences in 2019

- 28 March, Petter Holmström, An experimental and numerical study of the mechanical behaviour of short glass-fibre reinforced thermoplastics.
- 27 September, Emil Christiansen, Nanoscale Characterization of Deformed Aluminium Alloys.
- 8 October, Bjørn Håkon Frodal, Micromechanical modelling of ductile fracture in aluminium alloys.
- 21 October, Christian Oen Paulsen, Experimental Characterization of Two-Phase Steels.
- 7 November, Karoline Osnes, Monolithic and laminated glass under extreme loading: Experiments, modelling and simulations.
- 14 November, Susanne Thomesen, Plastic flow and fracture of isotropic and anisotropic 6000-series aluminium alloys: experiments and numerical simulations.
- 21 November, Matthias Reil, Connections between steel and aluminium using adhesive bonding combined with self-piercing riveting: Testing, modelling and analysis.

Research visits by SFI CASA staff

- PhD candidate Jonas Frafjord worked at SINTEF Raufoss from 21 January to 25 March.
- Researcher Petter Holmström worked at Equinor in Trondheim from April to June.
- PhD candidate Sindre Olufsen worked part-time at Equinor in the period September-December.
- Professor Randi Holmestad visited Monash Centre of Electron Microscopy, Monash University, Melbourne, Victoria, Australia from 30 September to 6 December.
- Professor Knut Marthinsen stayed at the University of Chongqing, China, from 1 November to 6 December.

Research visits at SFI CASA

- Vincent Faucher, French Alternative Energies and Atomic Energy Commission (CEA), Cadarache, France. 25-26 April and 9-14 December 2019.
- PhD student Rafael Sancho, Universidad Politécnica de Madrid, Spain. 30 April-1 August 2019.
- Professor Ahmed Benallal, LMT-Cachan, France. 11 June-3 July and 1-31 October 2019.
- Professor Jonas Faleskog, KTH, Sweden. 6-19 June 2019.
- Professor Norman Fleck, University of Cambridge, UK. 15-17 October 2019.
- PhD Sarah George, University of Cape Town, South Africa. August-December 2019.
- PhD candidate Kinga Somlo, DTU, Denmark. 2 December 2019 -27 March 2020.

Visiting MSc students

- Tim Koenis, TU Eindhoven, The Netherlands, November 2018-February 2019.
- Valentin Chopin, Paris-Sud University, France. February-March 2019.
- Guillaume Campagna, ENS Paric-Saclay, April-July 2019.
- Haddar Sleiman, TU München/BMW, Germany, April-July 2019.
- Maisie Ann Edwards-Mowforth, University of Edinburgh, UK, June-September 2019.
- Thijs Cals, TU Eindhoven, The Netherlands, September-November 2019.

Concurrent projects

- KPN project SLADE on fundamental investigations of violent wave actions and impact response (2019-2021). 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. The project employs Associate Professor Vegard Aune and one post doc at the SIMLab research group.
- Aluminium alloys with mechanical properties and electrical conductivity at elevated temperatures, AMPERE (2015-2020): The focus of this competence enhancement project is to study the properties of aluminium alloys at elevated temperatures. Professors Randi Holmestad and Knut Marthinsen are involved in this project.
- Fundamentals of Intergranular Corrosion in Aluminium Alloy, FICAL (2015-2020): The objective of this competence enhancement project is to establish new fundamental understanding of the mechanisms of intergranular corrosion (IGC) susceptibility. Professors Randi Holmestad and Knut Marthinsen are involved in this project.
- Rational Alloy Design, ALLDESIGN (2018-2022): NTNU project on digital materials design of aluminium-based alloys. PhD student Marcos Fernandez at CASA is involved in the project.
- Microstructure based modelling of ductile fracture in aluminium alloys, FractAl (2015-2020): 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 the Royal Institute of Technology in Sweden. The FractAl project employs one researcher, two post docs and four PhD candidates.
- FlexLinerLife (2017-2019): The SIMLab group was involved in this project as one of several consortium participants from Norway and Brazil. The project topic is flexible risers for the offshore oil and gas industry.
- KPN project 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.

PERSONNEL

The whole group, dressed up for Christmas. *1st row from left: Panagiotis Manoleas, Maria Jesus Perez Martin, Sunita Mishra, Kristin Qvale, Susanne Thomesen, Bjørn Håkon Frodal, Benjamin Stavnar Elveli, Kristoffer Aune Brekken, Vetle Espeseth, Henrik Granum, Magnus Langseth, Joakim Johnsen, Vegard Aune. 2nd row: Emil Christiansen, Asle Joachim Tomstad, Sondre Bergo, Jianbin Xu, Kinga Somlo, Borja Erice, Marcos Fernandez, Ruben Løland Sælen, Victor André, Jonas Rudshaug, Einar Schwenke, Karoline Osnes, Ole Vestrum, Peter Karlsaune. 3rd row : John Fredrick Berntsen, Knut Marthinsen, David Morin, Odd Sture Hopperstad, Lars Edvard Blystad Dæhli, Tore Børvik, Miguel Costas, Rene Kaufmann. 4th row: Petter Holmström, Arild Holm Clausen, Sølvi W. Normannsen, Torodd Berstad, Tore Wisth.* *(Photo: Ole Martin Wold)*

PhD candidates and post docs

PhD candidates and post docs with funding from SFI CASA

Name	Topic	Position	Start	Planned exam	Programme	Nationality	Gender
Petter Henrik Holmström*	Mechanical behaviour of short glass-fibre reinforced thermoplastics	PhD	2015	Defended in 2019	Polymeric	Norwegian	M
John Fredrick Berntsen*	Testing and modelling of multi-material joints	PhD	2015	2020	Structural Joints	Norwegian	M
Emil Christiansen*	Nanoscale Characterization of Deformed Aluminium Alloys	PhD	2015	Defended in 2019	Lower Scale	Norwegian	M
Bjørn Håkon Frodal*	Micromechanical modelling of ductile fracture in Aluminium Alloys	PhD	2015	Defended in 2019	Metallic Materials	Norwegian	M
Sindre Olufsen*	Modelling of ductile failure in polymers	PhD	2015	2020	Polymeric Materials	Norwegian	M
Karoline Osnes*	Monolithic and laminated glass under extreme loading: Experiments, modelling and simulations	PhD	2015	Defended in 2019	Structures	Norwegian	F
Christian Oen Paulsen**	Experimental Characterization of Two-Phase Steels.	PhD	2015	Defended in 2019	Lower Scale	Norwegian	M
Sondre Bergo**	Localization of plastic deformations in construction steel	PhD	2016	2020	Metallic Materials	Norwegian	M
Jonas Frafjord*	Multiscale modelling of deformation in Aluminium alloys	PhD	2016	2020	Lower Scale	Norwegian	M
Daniel Morton**	Modeling of the mechanical behaviour of polymer foams	PhD	2016	2020	Polymeric Materials	Norwegian	M
Matthias Reil**	Connections between steel and aluminium using adhesive bonding combined with self-piercing riveting	PhD	2016	Defended in 2019	Structural Joints	German	M
Ole Vestrum**	Optimisation of protective structures	PhD	2016	2020	Structures	Norwegian	M
Jianbin Xu**	Work hardening and Portevin-Le Chatelier (PLC) effect	PhD	2016	2020	Lower Scale	Chinese	M
Kristoffer Aune Brekken**	Modelling and Optimization of Sacrificial Claddings	PhD	2017	2021	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	2021	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
Maria Jesus Perez*	Impact of steel at low temp/Ductile fracture of high-strength steel	Post doc	2018	2020	Metallic Materials	Spanish	F
Panagiotis Manoleas**	Steel joints	Post doc	2018	2020	Metallic Materials	Greek	M
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
Sunita Mishra*	Blast loading	Post doc	2019	2020	Structures	Indian	F

**Salary and operational costs from the Centre.*

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

PhD candidates and post docs on concurrent projects. The topics are highly relevant for SFI CASA

Name	Topic	Position	Start	Planned exam	Topic/project	Nationality	Gender
Henrik Granum	Multiscale modelling and simulation of failure in aluminium structures	PhD	2016	2020	FractAl	Norwegian	M
Susanne Thomesen	Plastic flow and fracture of isotropic and anisotropic 6000-series aluminium alloys	PhD	2016	Defended in 2019	FractAl	Norwegian	F
Asle Joachim Tomstad	Quasi-static and dynamic ductile fracture of aluminium alloys under low triaxiality	PhD	2017	2021	FractAl	Norwegian	M
Kristin Qvale	Microstructure-based modelling and simulation of ductile fracture in aluminium alloys	PhD	2018	2021	FractAl	Norwegian	F
Vetle Espeseth	Microstructure-based modelling and simulations of plasticity and fracture in aluminium alloys	PhD	2018	2022	FractAl	Norwegian	M
Lars Edvard Dæhli	Micromechanical modelling of ductile failure in aluminium alloys	Post doc	2017	2021	FractAl	Norwegian	M
Bjørn Håkon Frodal	Modelling of aluminium	Post doc	2019	2021	FractAl	Norwegian	M
Rene Kaufmann	Impact response	Post doc	2019	2021	SLADE	German	M

Recruitment

Three new PhD candidates started at SFI CASA in 2019:
Victor André has an MSc from TU Dresden, Germany. Jonas Rudshaug and Ruben Løland Sælen are former MSc students at NTNU.
Sunita Mishra earned her doctoral degree at Indian Institute of Technology Delhi in 2019. She was hired as post doc at CASA from June 2019. Four of the six PhD candidates who defended their theses in 2019 have been hired as post docs at CASA and concurrent project FractAl.

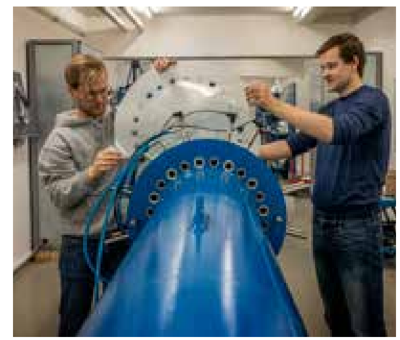
The Centre has had six visiting MSc students and one visiting PhD candidate in 2019, see page 42-43.

SFI CASA´s ambition is to attract Norwegian candidates and improve the gender balance. On 1 April, students from relevant NTNU study programmes were invited to a recruitment seminar.

The Centre has given guided tours for a total of 140 upper secondary school students during 2019. In addition, three guided tours were given to different groups of professionals. Among these were national and international industry, researchers from other universities, members of the Norwegian Government, and representatives from public agencies.

MSc students
The following MSc students were associated with the Centre in 2019

Name	Sex M/F	Topic
Anders Berrum	M	Dynamic response of flexible structures subjected to blast loading
Chris-Mikael Rom Bjorvand	M	Dynamic response of flexible structures subjected to blast loading
Håkon Dahle	M	Thermomechanical Response of Virgin and Degraded PA11
Fredrik Bonnevie Dahler	M	Testing and modeling of thick aluminum castings under impact loadings
Eyvind Evensen	M	Modelling of windshields subjected to quasi-static loading
Kristian Ullern Faksvåg	M	Material parameters for stainless steel in numerical analyses
Anders Hald	M	Dynamic response of steel plates subjected to combined impact and blast loading
Lars Omland Jakobsen	M	Material parameters for stainless steel in numerical analyses
Håvard Houmb Kristiansen	M	Dynamic response of blast-loaded steel plates with and without pre-formed holes
Guri Lillehaug	F	Combined impact and blast loading on concrete plates
Marte Vestermo Nesje	F	Combined impact and blast loading on concrete plates
Jonas Rudshaug	M	Modelling of windshields subjected to quasi-static loading
Ole Kristian Rønning	M	Thermomechanical Response of Virgin and Degraded PA11
Gunnar Sigstad	M	Dynamic response of blast-loaded steel plates with and without pre-formed holes
Ruben Løland Sælen	M	Dynamic Behaviour of Polymeric Foams
Nicholas Thuve	M	Testing and modeling of thick aluminum castings under impact loadings



The following lists journal publications and conference contributions generated in 2019.

Journal articles

1. M.E. Andersen, O.S. Hopperstad, A.H. Clausen. Volumetric strain measurement of polymeric materials subjected to uniaxial tension. Strain 55(4) (2019).
2. J.F. Berntsen, D. Morin, A.H. Clausen, M. Langseth. Experimental investigation and numerical modelling of the mechanical response of a semi-structural polyurethane adhesive. International Journal of Adhesion and Adhesives 95 (2019) 102395.
3. E. Christiansen, C.D. Marioara, B. Holmedal, O.S. Hopperstad, R. Holmestad. Nano-scale characterisation of sheared β″ precipitates in a deformed Al-Mg-Si alloy. Scientific Reports 9 (2019) 17446.
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5. S. Dumoulin, T. Coudert, O.S. Hopperstad. ATLAS of yield surfaces for strongly textured FCC polycrystals. AIP Conference Proceedings 2113 (2019) 180008.
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7. M. Kristoffersen, A. Minoretti, T. Børvik. On the internal blast loading of submerged floating tunnels in concrete with circular and rectangular cross-sections. Engineering Failure Analysis 103 (2019) 462-480.
8. D. Morin, L.E.B. Dæhli, T. Børvik, A. Benallal, O.S. Hopperstad. Numerical study of ductile failure under non-proportional loading. European Journal of Mechanics. A, Solids 74 (2019) 221-241.
9. S.N. Olufsen. AXITOM: A Python package for reconstruction of axisymmetric tomograms acquired by a conical beam. Journal of Open Source Software 4(42) (2019) 1704.
10. S.N. Olufsen, A.H. Clausen, O.S. Hopperstad. Influence of stress triaxiality and strain rate on stress-strain behaviour and dilation of mineral-filled PVC. Polymer testing 75 (2019) 350-357.
11. K. Osnes, S. Dey, O.S. Hopperstad, T. Børvik. On the dynamic response of laminated glass exposed to impact before blast loading. Experimental mechanics 57(7) (2019) 1033-1046.
12. K. Osnes, J.K. Holmen, O.S. Hopperstad, T. Børvik. Fracture and fragmentation of blast-loaded laminated glass: An experimental and numerical study. International Journal of Impact Engineering 132 (2019) 132, 1-17.
13. M.J. Perez Martin, J.K. Holmen, S. Thomesen, O.S. Hopperstad, T. Børvik. Dynamic Behaviour of a High-Strength Structural Steel at Low Temperatures. Journal of Dynamic Behavior of Materials 5(3) (2019) 241-250.
14. Aa. Reyes, T. Børvik. Low velocity impact on crash components with steel skins and polymer foam cores. International Journal of Impact Engineering 132 (2019) 103297.
15. J.K. Sunde, E. Christiansen, E. Thronsen, S. Wenner, C.D. Marioara, S. Van Helvoort, R. Holmestad. Scanning Precession Electron Diffraction to aid Aluminum Alloy Development. Microscopy and Microanalysis 25 (2) (2019) 1920-1921.
16. O. Vestrum, M. Langseth, T. Børvik. Finite element modeling of porous polymer pipeline coating using X-ray micro computed tomography. Composites Part B: Engineering 172 (2019) 406-415.

Conference contributions 2019

1. V. Aune. Aluminium structures exposed to blast loading. Lightweight solutions for Marine and Offshore. 12-13 February, Ålesund, Norway.
2. S. Bergo, O.S. Hopperstad, D. Morin, T. Børvik. Micromechanics-based identification of a fracture model for three structural steels. COMPLAS, 2-6 September 2019, Barcelona, Spain.
3. J.F. Berntsen, D. Morin, A.H. Clausen, M. Langseth. Modelling of bonded component tests - Comparing MAT_240 to state-of-the-art model. 12th European LS-DYNA conference, 14-16 May 2019, Koblenz, Germany.
4. T. Børvik. Testing, modelling and simulation of plain and laminated glass under impact and blast loading. EuroMech Colloquium: Damage and failure of engineering materials under extreme loading conditions, 21-24 May 2019, Madrid, Spain.
5. E. Christiansen, C.D. Marioara, R. Bjørge, I.G. Ringdalen, B. Holmedal, O.S. Hopperstad, R. Holmestad. (S)TEM characterisation and simulations of sheared '' precipitates in a deformed Al-Mg-Si alloy. 5th Forum of Center for Advanced Materials Research and International Collaboration (CAMRIC-FORUM5), 3-4 October 2019, Toyama, Japan.
6. E. Christiansen, I.G. Ringdalen, R. Bjørge, C.D. Marioara, R. Holmestad. TEM image simulations of overlapping phases - a case study of sheared β″ precipitates in Al-Mg-Si alloys. EMAG, 1-4 July 2019, Manchester, United Kingdom.
7. M. Costas, D. Morin, M. Langseth. An experimental and numerical study on the lateral crushing of additively manufactured AlSi10Mg boxes. ESIAM19, First European Conference on Structural Integrity of Additively Manufactured Materials, 9-11 September 2019, Trondheim, Norway.
8. M. Costas, D. Morin, M. Langseth. Modelling and Simulation of Impact in Stiffened Aluminium Panels Using Damage Regularisation. ASIDIC2019, Aerospace Structural Impact Dynamics International Conference, 4-6 June 2019, Madrid, Spain.
9. M. Costas, M. Kristoffersen, D. Morin, T. Børvik, M. Langseth. Testing and simulation of SLM AlSi10Mg under large deformations. Workshop of the Aluminium Innovation Hub: Digitalisation for smart processes and product design, 12-13 June 2019, Trondheim, Norway.
10. M. Costas, D. Morin, M. Langseth. Multi-Scale Numerical Simulations of Structural Joints with Flow-Drill Screws using a Virtual Material Calibration. 12th European LS-DYNA Conference 2019, 14-16 May 2019, Koblenz, Germany.
11. B. Erice, M.J. Perez Martin, D. Morin, T. Børvik, O.S. Hopperstad. Plastic Instability Mechanisms due to Surface Imperfections in Largely Strained Metallic Materials. XV International Conference on Computational Plasticity. COMPLAS 2019, 3-5 September 2019, Barcelona, Spain.
12. M. Fernandez, D. Morin, O.S. Hopperstad. Modelling of aluminium components under large deformations. Workshop of the Aluminium Innovation Hub: Digitalisation for smart processes and product design, 12-13 June 2019, Trondheim, Norway.
13. J. Frafjord, J. Friis, S. Wenner, B. Holmedal, R. Holmestad, I.G. Ringdalen. The Effect of Multiple Solute Species in Solute Strengthening in Aluminium Alloys - MD study. Dislocations 2019, 15-21 October 2019, Haifa, Israel.
14. B.H. Frodal, D. Morin, T. Børvik, O.S. Hopperstad. On the effect of plastic anisotropy, strength and work hardening on the tensile ductility of aluminium alloys. Workshop of the Aluminium Innovation Hub: Digitalisation for smart processes and product design, 12-13 June 2019, Trondheim, Norway.

15. M. Gazizov, J.K. Sunde, E. Christiansen, E. Thronsen, A. Lervik, S. Wenner, C.D. Marioara, R. Holmestad. Precipitates in aluminium alloys – studied by advanced (S)TEM techniques. Microscience Microscopy Congress (MMC) – EMAG, 1-4 July 2019, Manchester, United Kingdom.
16. J.K. Holmen, O.S. Hopperstad, T. Børvik. Perforation resistance of aluminium structures. Workshop of the Aluminium Innovation Hub: Digitalisation for smart processes and product design, 12-13 June 2019, Trondheim, Norway.
17. R. Holmestad. Precipitation in Aluminium alloys – studied with advanced TEM. XXII Physical Metallurgy and Materials Science Conference: Advanced Materials and Technologies AMT 2019, 9-12 June 2019, Bukowina, Poland.
18. J.K. Sunde, E. Christiansen, E. Thronsen, S. Wenner, C.D. Marioara, A. Van Helvoort, R. Holmestad. Scanning Precession Electron Diffraction to Aid Aluminum Alloy Development. Microscopy and microanalysis, 4-8 August 2019, Portland OR, USA.
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20. R. Holmestad. Precipitation in age hardenable Al alloys -studied at the nanoscale. Monash Centre of Electron Microscopy (MCEM), 27 November 2019, Melbourne, Australia.
21. O.S. Hopperstad. Towards a virtual laboratory for aluminium structures. Workshop of the Aluminium Innovation Hub: Digitalisation for smart processes and product design, 12-13 June 2019, Trondheim, Norway.
22. O.S. Hopperstad. Failure of blast-loaded aluminium plates: experiments, modelling and numerical simulations. Century Fracture Mechanics Summit, 8-10 April 2019, Singapore.
23. O.S. Hopperstad. Towards a virtual laboratory for aluminium structures. LS-DYNA European Conference 2019, 14-16 May 2019, Koblenz, Germany.
24. J. Johnsen, J.K. Holmen, G. Gruben, D. Morin, M. Langseth. Calibration and application of GISSMO and *MAT_258 for shell element simulations of high-strength steel. 12th European LS-DYNA conference, 14-16 May 2019, Koblenz, Germany.
25. M. Kristoffersen, M. Costas, C.O. Paulsen, T. Koenis, V. Brøtan, T. Børvik. Experimental and numerical investigations of additively manufactured AlSi10Mg plates subjected to ballistic perforation. European Conference on the Structural Integrity of Additively Manufactured Materials (ESIAM19), 9-11 September 2019, Trondheim, Norway.
26. M. Kristoffersen, K.O. Hauge, A. Minoretti, T. Børvik. Blast loading of concrete: Simulations of tubular structures subjected to internal detonations. 12th European LS-DYNA Conference, 14-16 May 2019, Koblenz, Germany.
27. M. Kristoffersen, D. Morin, O.S. Hopperstad, T. Børvik. Localisation analysis in an X65 offshore pipeline steel. 38th International Conference on Ocean, Offshore & Arctic Engineering, 9-14 June 2019, Glasgow, United Kingdom.
28. M. Kristoffersen, D. Morin, O.S. Hopperstad, T. Børvik. Numerical analyses of localisation in steel subjected to non-proportional loading. Computational Plasticity 2019 (COMPLAS XV), 3-5 May 2019, Barcelona, Spain.
29. M. Langseth. Aluminium as a structural material. Lightweight solutions for Marine and Offshore, 12-13 February 2019, Ålesund, Norway.
30. M. Langseth. Research on connections between steel and aluminium in an automotive industrial context. Century Fracture Mechanics Summit, 8-10 April 2019, Singapore.
31. J. Xu, B. Holmedal, O.S. Hopperstad, K. Marthinsen. Experimental characterization and modelling of the PLC effect in an Al-Mg alloy. The 3rd International Symposium on Advanced Structural Materials – Deformation and Strengthening Mechanisms, 1-4 November 2019, Chongqing, China
32. M. Remøe, I. Westermann, K. Martinsen. The role of dispersoids and characterization of their density and spatial distribution during thermomechanical processing of Al-alloys. Japanese Institute of Light Metals, Spring Meeting, 10-13 May, 2019, Toyama, Japan.
33. D. Morin. Towards a virtual laboratory for the design of aluminium structures: automotive applications. 1st International Workshop on Plasticity, Damage and Fracture of Engineering Materials, 22-23 August 2019, Ankara, Turkey.
34. D. Morin, T. Berstad, M. Costas, O.S. Hopperstad, M. Langseth. *MAT_258: A Through-Thickness Regularization Scheme for Shell Element Analyses – Application to Aluminium Components. 12th European LS-DYNA Conference 2019, 14-16 May 2019, Koblenz, Germany.
35. D. Morin, M. Reil, T. Berstad, M. Costas, M. Langseth. Modelling of Steel-Aluminium Components using Structural Adhesive and Self-Piercing Rivets. 12th European LS-DYNA Conference 2019, 14-16 May 2019, Koblenz, Germany.
36. S.N. Olufsen, A.H. Clausen, O.S. Hopperstad. In-Situ X-ray tomography for investigation of void growth in mineral-filled PVC using a conventional X-ray source: A plausibility study. Nordic Polymer Days 2019, 5-7 June 2019, Trondheim, Norway.
37. M.J. Perez Martin, J.K. Holmen, S. Thomesen, O.S. Hopperstad, T. Børvik. Dynamic Behaviour of a High-Strength Structural Steel at Low Temperatures. 24th DYMAT Technical Meeting: Temperature dependence of material behaviour at high strain-rates, 9-11 September 2019, Stresa, Italy.
38. E. Schwenke, D. Morin, A.H. Clausen. Modelling of polypropylene subjected to impact loading at low temperatures. 12th European LS-DYNA conference, 14-16 May 2019, Koblenz, Germany.
39. O. Vestrum, M. Langseth, T. Børvik. Mechanical modeling of the polymeric coating on a subsea pipeline. 38th International Conference on Ocean, Offshore and Arctic Engineering, 9 June 2019, Glasgow, UK.

Other publications

1. V. Aune, G. Valsamos, F. Casadei, T. Børvik. Aspects of fluid-structure interaction on the dynamic response of blast-loaded metallic plates. Proceedings of the Light-Weight Armour Group for Defense and Security Conference (2019) 102-111 ISBN 9782955791219.
2. J. Díaz, M. Costas. Crashworthiness. Encyclopedia of Continuum Mechanics. Springer. ISBN 978-3-662-53605-6
3. B.S. Elveli, T. Børvik, V. Aune. Blast-load response of thin steel plates after ballistic impact from small-arms projectiles. Proceedings of the Light-Weight Armour Group for Defense and Security Conference (2019) 166-175 ISBN 9782955791219.
4. O. Vestrum, M. Langseth, T. Børvik. Mechanical modeling of the polymeric coating on a subsea pipeline. ASME 2019 38th International Conference on Ocean, Offshore and Arctic Engineering. Volume 3: Structures, Safety, and Reliability. ASME Press (2019) ISBN 978-0-7918-5878-3.

PhD theses

- Emil Christiansen, Nanoscale Characterization of Deformed Aluminium Alloys.ISBN 978-82-326-4101-7
- Bjørn Håkon Frodal, Micromechanical modelling of ductile fracture in aluminium alloys. ISBN 978-82-326-4103-1.
- Petter Henrik Holmström, An experimental and numerical study of the mechanical behaviour of short glass-fibre reinforced thermoplastics. ISBN 978-82-326-3761-4.
- Karoline Osnes, Monolithic and laminated glass under extreme loading: Experiments, modelling and simulations. ISBN 978-82-326-4205-2.
- Christian Oen Paulsen, Experimental Characterization of Two-Phase Steels. ISBN 978-82-326-4147-5.
- Matthias Reil, Connections between steel and aluminium using adhesive bonding combined with self-piercing riveting: Testing, modelling and analysis. ISBN 978-82-326-4235-9.
- Susanne Thomesen, Plastic flow and fracture of isotropic and anisotropic 6000-series aluminium alloys: experiments and numerical simulations. ISBN 978-82-326-4221-2.

Publications on concurrent projects

Journal articles

1. L.E.B. Dæhli, O.S. Hopperstad, A. Benallal. Effective behaviour of porous ductile solids with a non-quadratic isotropic matrix yield surface. Journal of the mechanics and physics of solids 130 (2019) 56-81.
2. H. Granum, V. Aune, T. Børvik, O.S. Hopperstad. Effect of heat-treatment on the structural response of blast-loaded aluminium plates with pre-cut slits. International Journal of Impact Engineering 132 (2019) 103306.
3. J. Johnsen, A.H. Clausen, F. Grytten, A. Benallal, O.S. Hopperstad. A thermo-elasto-viscoplastic constitutive model for polymers. Journal of the Mechanics and Physics of Solids 124 (2019) 681-701.
4. M. Khadyko, D. Morin, T. Børvik, O.S. Hopperstad. Tensile ductility of extruded aluminium alloy AA6063 in different tempers. Materials Science & Engineering: A 744 (2019) 500-511.
5. M. Khadyko, O.R. Myhr, O.S. Hopperstad. Work hardening and plastic anisotropy of naturally and artificially aged aluminium alloy AA6063. Mechanics of materials 136 (2019) 103069.
6. D. Morin, L.E. Dæhli, T. Børvik, A. Benallal, O.S. Hopperstad. Numerical study of ductile failure under non-proportional loading. European Journal of Mechanics. A, Solids 74 (2019) 221-241.

Conference contributions

1. L.E.B. Dæhli, D. Morin, T. Børvik, A. Benallal, O.S. Hopperstad. Effects of Lode-dependent matrix behaviour on the macroscopic yielding and ductile failure in isotropic porous plastic solids. CFRAC2019, 12-14 June 2019, Braunschweig, Germany.
2. L.E.B. Dæhli, D. Morin, T. Børvik, A. Benallal, O.S. Hopperstad. Influence of matrix yield surface curvature on the effective yielding and ductile failure of isotropic porous plastic materials. Workshop of the Aluminium Innovation Hub: Digitalisation for smart processes and product design, 12-13 June, Trondheim, Norway.
3. V. Espeseth, D. Morin, T. Børvik, O.S. Hopperstad. The effects from size and volume fraction of intermetallic particles on ductile failure: a numerical study. COMPLAS 2019, 3-5 September 2019, Barcelona, Spain.
4. H. Granum, V. Aune, T. Børvik, O.S. Hopperstad. Aluminium plates with pre-formed slits subjected to blast loading. Aluminium Innovation Workshop, 12-13 June, Trondheim, Norway.
5. H. Granum, D. Morin, T. Børvik, O.S. Hopperstad. Simulation of blast-loaded aluminium plates with geometrical defects. MekIT 19 National Conference on Computational Mechanics, 3-4 June 2019, Trondheim, Norway.
6. H. Granum, D. Morin, T. Børvik, O.S. Hopperstad. Simulation of blast-loaded aluminium plates with crack-like defects. I: MekIT'19 - 10th National Conference on Computational Mechanics. International Center for Numerical Methods in Engineering (2019) 149-164, ISBN 978-84-949194-9-7.
7. O.S. Hopperstad. Towards a virtual laboratory for aluminium structures. LS-DYNA European Conference 2019, 14-16 May 2019, Koblenz, Germany.
8. O.S. Hopperstad, H. Granum, D. Morin, V. Aune, T. Børvik. Dynamic failure of aluminium plates with geometrical defects. European Mechanics Society Colloquium on "Damage and failure of engineering materials under extreme loading conditions", 21-24 May 2019, Madrid Spain.
9. K. Qvale, H. Granum, O.S. Hopperstad, T. Børvik. Quasi-static and dynamic crushing of aluminium profiles. Workshop of the Aluminium Innovation Hub: Digitalisation for smart processes and product design, 12-13 June2019, Trondheim, Norway.

Ballistic Impact on Concrete Plate. The test is part of a 3-year project set up to develop complete and cost-effective protective solutions for buildings exposed to missile impact. Head of the project is SFI CASA´s partner Norwegian Defence Estates Agency (NDEA). The project join forces with Professor Tore Børvik and researcher Martin Kristoffersen at CASA.
(Photo: Sølvi W. Normannsen)

Annual accounts

SFI CASA FUNDING 2019 (ALL FIGURES IN 1000 NOK)

Item	Host NTNU	Research partner SINTEF	Public partners	Industrial partners	RCN grant	Total funding
Research programmes	6994	1100	2711	7155	12870	30830
Equipment				635		635
Administration	1000		1439	3410		5849
Total budget	7994	1100	4150	11200	12870	37314

SFI CASA COSTS 2019 (ALL FIGURES IN 1000 NOK)

Item	Host NTNU	Research partner SINTEF	Public partners	Industrial partners	Total cost
Research programmes	22680	4550	700	2900	30830
Equipment	635				635
Administration	5299	550			5849
Total budget	28614	5100	700	2900	37314

Spin-off company ENODO

The name comes from Latin and means to enlighten, to analyse, or to untie a knot. Spin-off company Enodo specialises in finite element simulations of aluminium, steel and polymers. Their products are material cards and otherwise data and modelling services for commercial FE solvers like LS-DYNA, Abaqus and PAM-CRASH.

In the beginning, Enodo focuses on the Energy, Automotive, Maritime and Buildings markets in the Nordic region and Northern Europe.

Enodo is a result of the FORNY2020 verification project (2018-2019) funded by the Research Council of Norway. In October 2018 it was established as the first commercial company based on the research in SIMLab and SFI CASA.

Owners of Enodo are NTNU and the founders, Joakim Johnsen and Jens Kristian Holmen.

WEBSITE: www.enodo.no

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 research-intensive 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:

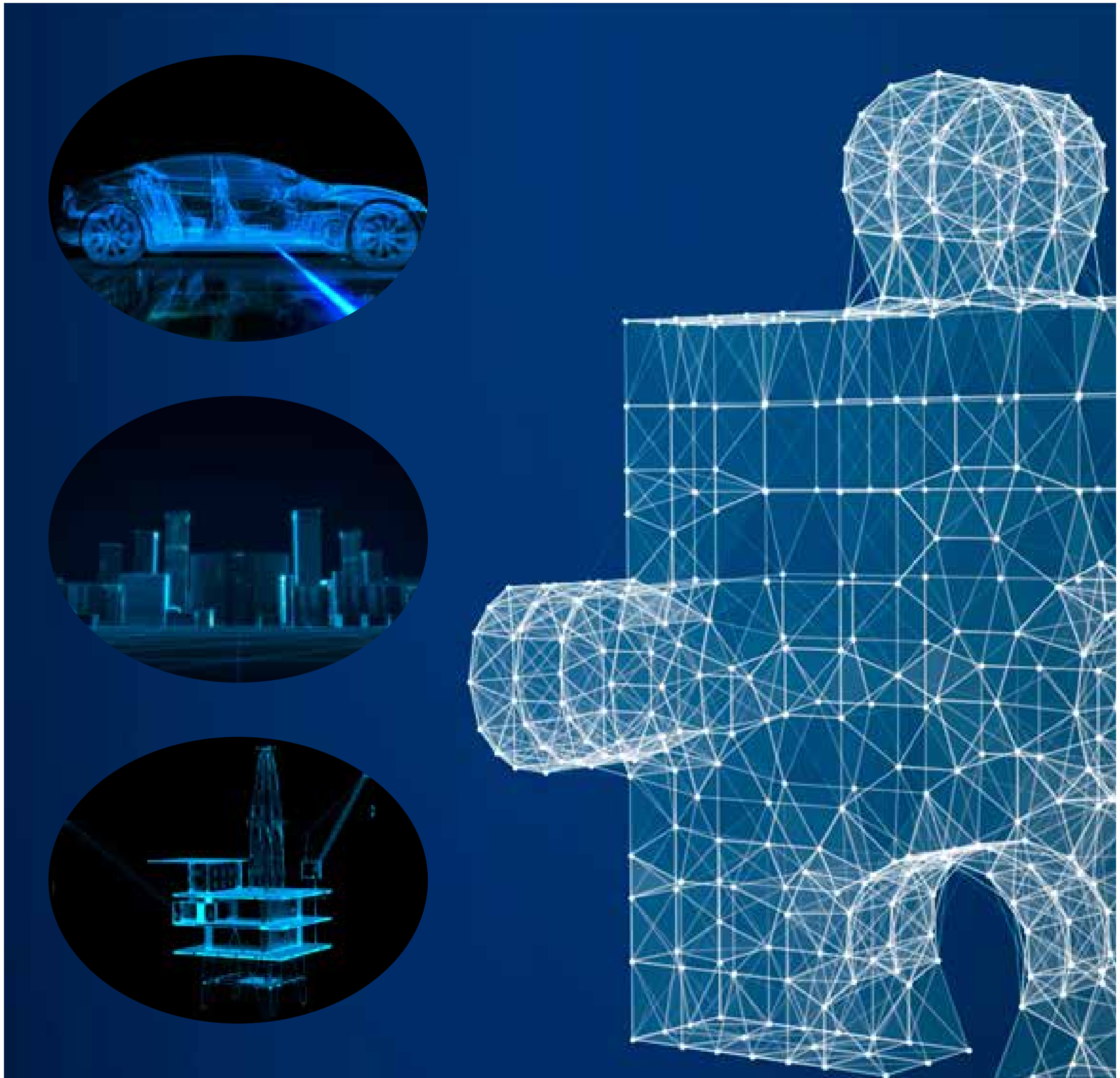
SFI SIMLab is history; the SIMLab research group is alive and kicking. All the more comforting, since the group carries with it all the expertise that brought SFI SIMLab to a world-leading position in the design of crashworthy and protective structures.

CASA is an SFI

CASA, Centre for Advanced Structural Analysis, is the name of the second 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. New materials such as glass are included.



SFI CASA develops 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. (Illustrations: Shutterstock)

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