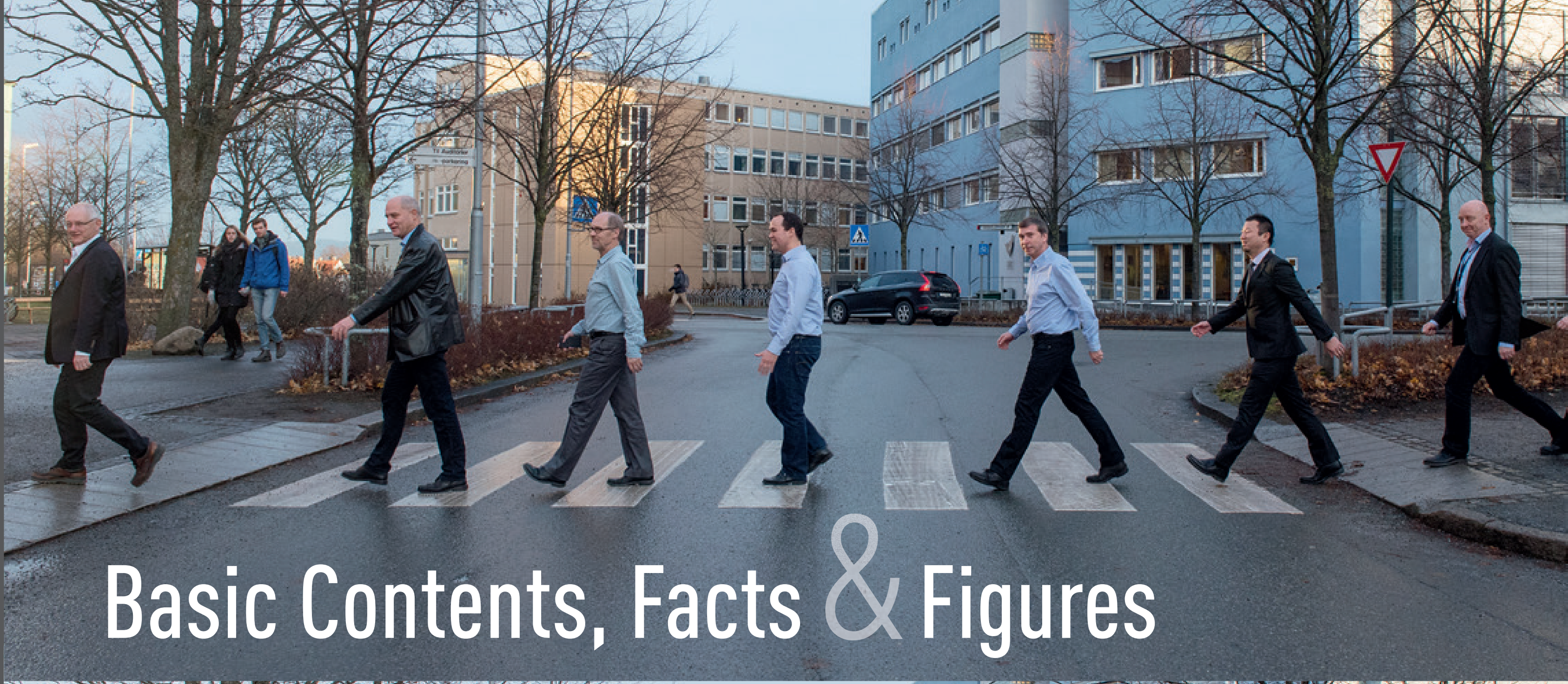
CASA

Annual Report 2016

Centre for Advanced Structural Analysis



Basic Contents, Facts & Figures

sfi Centre for Research-based Innovation

SINTEF

NTNU

sapa:

HYDRO

AkerSolutions

DNV·GL

HONDA

GASSCO

NSM

Forsvarsbygg

BENTELER
Automotive

TOYOTA

SSAB

BMW

Audi

NORWEGIAN MINISTRY OF
LOCAL GOVERNMENT AND MODERNISATION

Statoil

Statens vegvesen

CONTACT – RESPONSE

Professor Magnus Langseth
Dr. ing., Centre Director
Phone: +47 73 59 47 82
Mobile: +47 930 37 002
Email: magnus.langseth@ntnu.no

Peter Karlsaune, Coordinator
Phone: +47 73 59 46 72
Mobile: +47 450 02 177
Email: peter.karlsaune@ntnu.no

Albert H. Collett,
Communication Officer
Phone: +47 73 59 07 93
Mobile: +47 917 66 127
Email: albert.collett@ntnu.no

Website: ntnu.edu/casa
Newsletter: sfi-casa.no

POSTAL ADDRESS
SFI CASA,
Department of Structural Engineering,
NTNU, NO-7491 Trondheim, Norway

OFFICE LOCATION
NTNU, Richard Birkelands vei 1a,
Trondheim, Norway

COVER
CASA Board does Abbey Road after the meeting in November.

Top from left: Asbjørn Rolstadås, Chair, NTNU, Magnus Langseth, Director, CASA, Jan Strid, Sapa, Andreas Koukal, Audi, Helge Langberg, Norwegian Defence Estates Agency, Satoru Miyagano, Toyota Motor Europe, Rudie Spooren, SINTEF.

Bottom from left: Agnes Marie Horn, DNV GL, Øivind Mandt, Norwegian National Security Agency, Gina Ytteborg, Norwegian Public Roads Administration, Atle Stenseth, Gassco, Octavian Knoll, BMW, Eric DeHoff, Honda R&D Americas, Anders Artelius, Benteler Aluminium Systems Norway, Ole Runar Myhr, Hydro.

PHOTOS
All photos this section Lena Knutli except pp. 13 and 21–22.

GRAPHIC DESIGN
NTNU Grafisk senter

CONTENTS

SUMMARY

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 (NTNU) in close cooperation with Department of Materials Science and Engineering and Department of Physics, also at NTNU. SINTEF Materials and Chemistry is the research partner.

The industrial partners in 2016 were Audi AG, Benteler Aluminium Systems Norway AS, BMW Group, DNV GL AS, Gassco AS, Honda R&D Americas Inc., Hydro Aluminium AS, Ministry of Local Government and Modernisation, Norwegian Defence Estates Agency, Norwegian National Security Authority, Norwegian Public Roads Administration, Sapa AB, SSAB, Statoil Petroleum AS, and Toyota Motor Europe. Aker Solutions and SSAB withdrew from the consortium at the end of 2016. Renault joined the Centre as a new partner from January 2017.

SFI CASA's board comprises representatives from all the partners. A director heads the daily operation, assisted by a core team and programme heads. A Scientific Advisory Board of international experts has been appointed to provide scientific and strategic advice. In addition, CASA has established an Industrial Reference Group to oversee and facilitate industrial implementation of the results generated in the Centre.

History

The activities in SFI CASA are based on the research platform generated in the SFI SIMLab Centre from 2007-2014. They preserve and further develop 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.

In this respect the developed integrated approach to structural problems involves all aspects necessary to make computational mechanics successful. This adds up to a unique platform for the research in CASA.

The SIMLab Tool Box is a collection of software products that enables the transfer of technology from the SIMLab Centre to CASA. This provides a foundation for further developments and seamless implementation at the user partners. CASA is much broader in scope than the previous centre. It represents a step change for advanced structural analysis for industry and public enterprises as it is based on multidisciplinary and interdisciplinary research on different physical scales.

Generic research

The Centre will develop validated computational tools for innovation with and for the partners working in the oil and gas industry, in transportation and with physical security. Although the partners represent different fields they have similar needs in advanced structural analysis. The basic research in the Centre is pre-competitive and generic. This facilitates cooperation and transfer of knowledge across business sectors. A multidisciplinary and interdisciplinary research approach based on multiscale testing, modelling and analysis in an industrial context is applied. Another characteristic is the top-down/bottom-up approach. The main goal is always the final structure of the product.

Research questions and programmes

Three core research questions form the basis for research at the Centre:

1. How can we establish accurate, efficient and robust constitutive models based on the chemical composition, microstructure and thermo-mechanical processing of a material?
2. How can we apply knowledge of material, geometry and joining technology to obtain optimal behaviour of hybrid structures for given load situations?
3. How can we describe the interaction between the load and the deformable structure under extreme loading scenarios?

Motivated by these questions, the Centre has defined five basic research programmes to increase the prediction accuracy of numerical simulations: Lower Scale, Metallic Materials, Polymeric Materials, Structural Joints, and Structures. Each programme has annual work plans with contributions from PhD candidates, post docs and scientists from the partners. The Methods and Tools and the Industrial Implementation activities serve as links between the basic research and the industrial need for the technology developed and are gathered in the SIMLab Tool Box for implementation at the industrial partners.

Meetings and seminars

The Centre organized several technical meetings and seminars with participants from the industrial partners through. The technical meetings are an arena to present the work in the research programmes and for discussions with the partners. The annual work plans are based on the discussions at the technical meetings. The Industrial Reference Group held its first meeting on 1 March and another meeting in November in conjunction with the CASA Seminar. A training seminar on the SIMLab Tool Box software took place in Trondheim in September 2016. There was a meeting and seminar with CASA's Scientific Advisory Board in Trondheim on 26-27 October and finally CASA held its annual Seminar and Board Meeting on 16-17 November.

SFI SIMLab

Some of the PhD projects in SFI SIMLab were not completed at its closure in 2014. They continue in SFI CASA as parallel projects as the topics are closely related. Two PhD candidates from SFI SIMLab and one PhD candidate on a concurrent project defended their theses in 2016:

Marius Andersen: An Experimental and Numerical Study of Thermoplastics at Large Deformations

Jens Kristian Holmen: Modelling and Simulation of Ballistic Impact

Arne Ilseng: Mechanical Behaviour of Particle-filled Elastomers at Various Temperatures. An Experimental and Numerical Study

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. CASA has cooperated with the following universities and research laboratories in 2016:

Ecole Normale Supérieure de Cachan/Laboratorie de Mécanique et Technologie (ENS/LMT), France; Federal University of Rio de Janeiro, Brazil; University of São Paulo, Brazil; Department of Materials Science and Engineering, University of Toyama, Japan; Department of Metallurgy and Ceramics Science, Tokyo Institute of Technology, Japan; IMPETUS Afea AB, Sweden; Joint Research Centre, Institute for the Protection and Security of the Citizen, Italy; Faculty of Engineering and the Environment, University of Southampton, UK; Purdue University, USA.

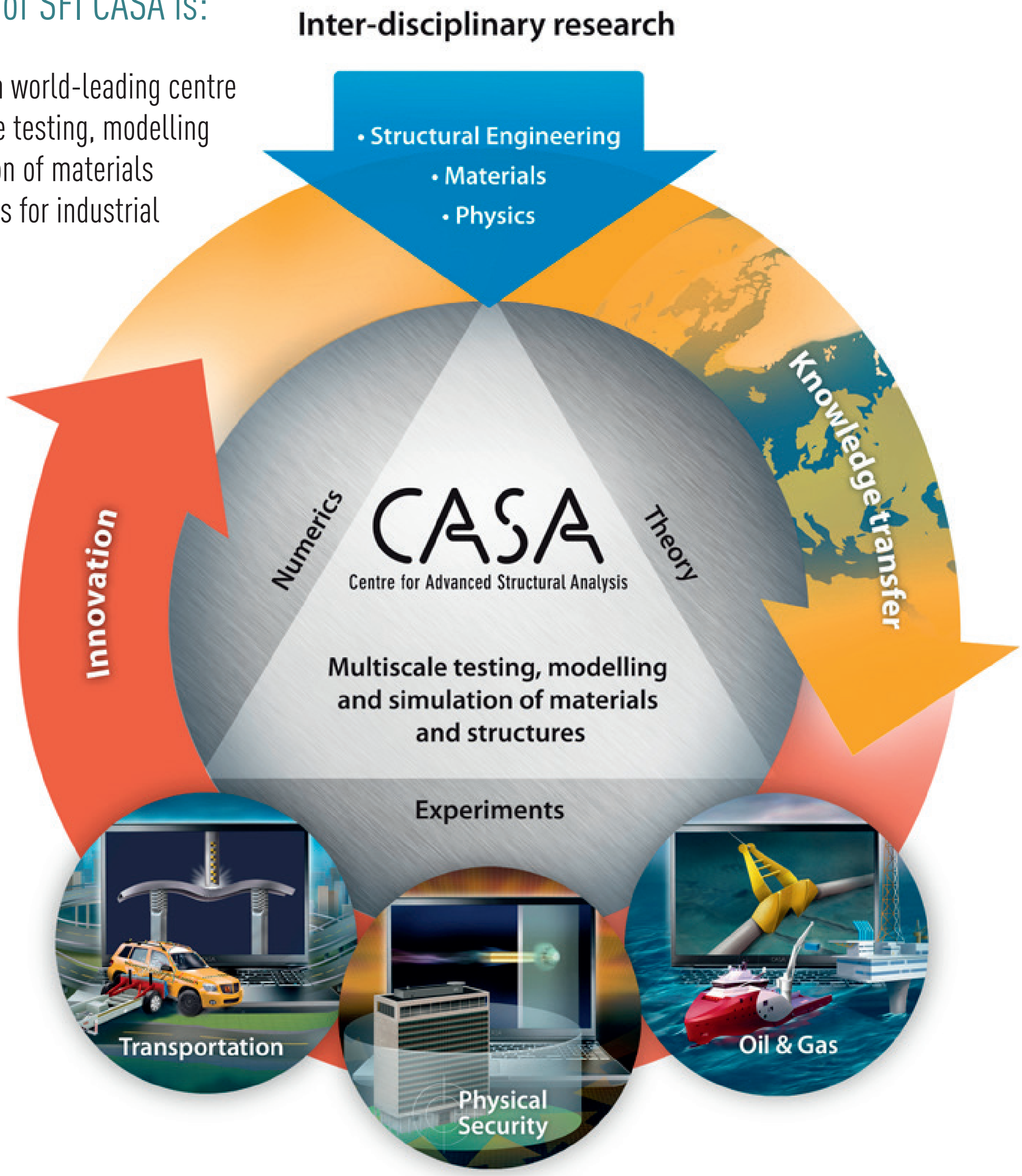
Visibility

CASA's media strategy aims at popular science presentations of its research activities. It is also an aim to make female researchers particularly visible in order to recruit female researchers and contribute to a more even gender balance in this research field. The popularized part of this report exemplifies how the strategies are carried out and contains articles from CASA's monthly newsletter.

Besides popular science presentations the importance of being visible in research is a given. In 2016 CASA published 21 articles in peer-reviewed journals and gave 15 conference presentations.

The vision of SFI CASA is:

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 (automotive and infrastructure along Norwegian roads) and in industry and public enterprises working with physical security (protection of critical infrastructure that could be subjected to terrorist acts and sabotage). Even though these partners represent different business sectors, they have similar needs in advanced structural analysis because the underlying theories and formulations behind the different computer tools are the same. Accordingly, the basic research in the Centre is precompetitive and generic in nature and can facilitate cooperation between the user partners and hence transfer knowledge across business sectors. This supports the success criteria defined by the Research Council of Norway for an SFI where research at a high international level is to create a platform for innovation and value creation. In order to facilitate the use of validated numerical simulations by the user partners and meet their technological roadmaps and business plans for process and product development, a multidisciplinary and interdisciplinary research approach based on multiscale testing, modelling and analysis in an industrial context is required. This represents a major research initiative that is only achievable for a centre with long-term objectives and funding.

Thus the main objective with 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.

VISION AND OBJECTIVE

GOALS AND RESEARCH PLAN

Goals

The main quantitative goals of the Centre are as follows:

Industrial: 1) To develop methods and tools for credible advanced structural analysis at the user partners. 2) To ensure transfer of technology across business sectors. 3) To implement the developed technology of the user partners. 4) To facilitate employment of post docs, MSc and PhD candidates at the user partners to strengthen the industrial implementation.

Academic: 1) To graduate 20 PhD candidates and employ 5 post docs. 2) To graduate 100-150 MSc students. 3) To attract 10 foreign 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 competiveness 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 at CASA. The research questions encompass the entire first five-year period as well as the possible subsequent three-year period for the Centre. However, additional research questions may emerge in the later phases of the Centre.

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.

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

Metallic Materials: This 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 will develop and improve material models representing the thermo-mechanical response up to fracture for polymers, i.e. thermoplastics with or without fibre reinforcement, foams 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 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 their possible combinations. The considered materials are steel, aluminium and reinforced polymers.

Structures: This 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. Actual materials are those typically used in protective structures such as steel, aluminium, polymers, glass, foams, ceramics and concrete.

Research methodology and industrial implementation

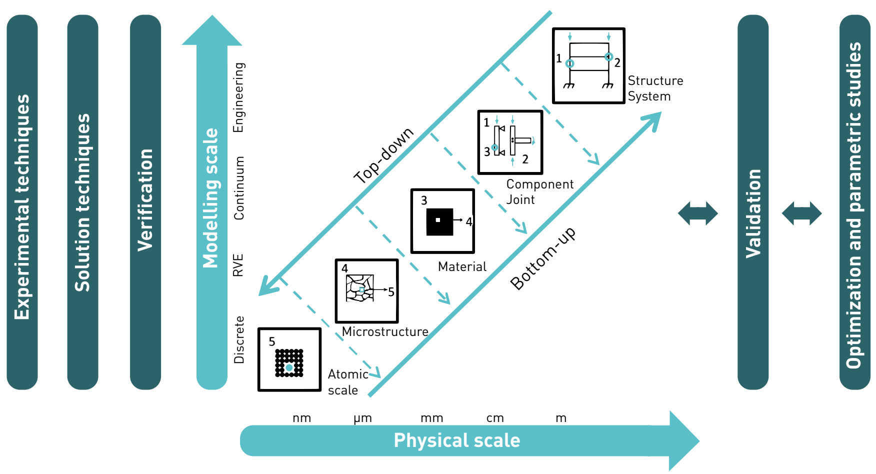


Figure 1: Research methodology.

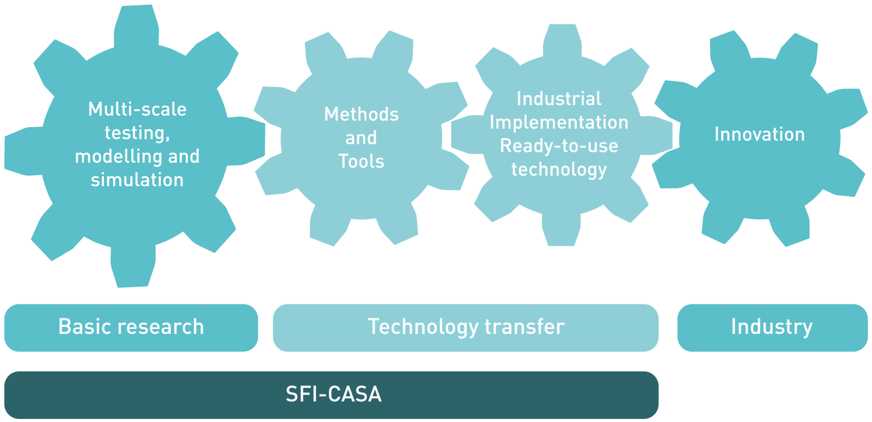
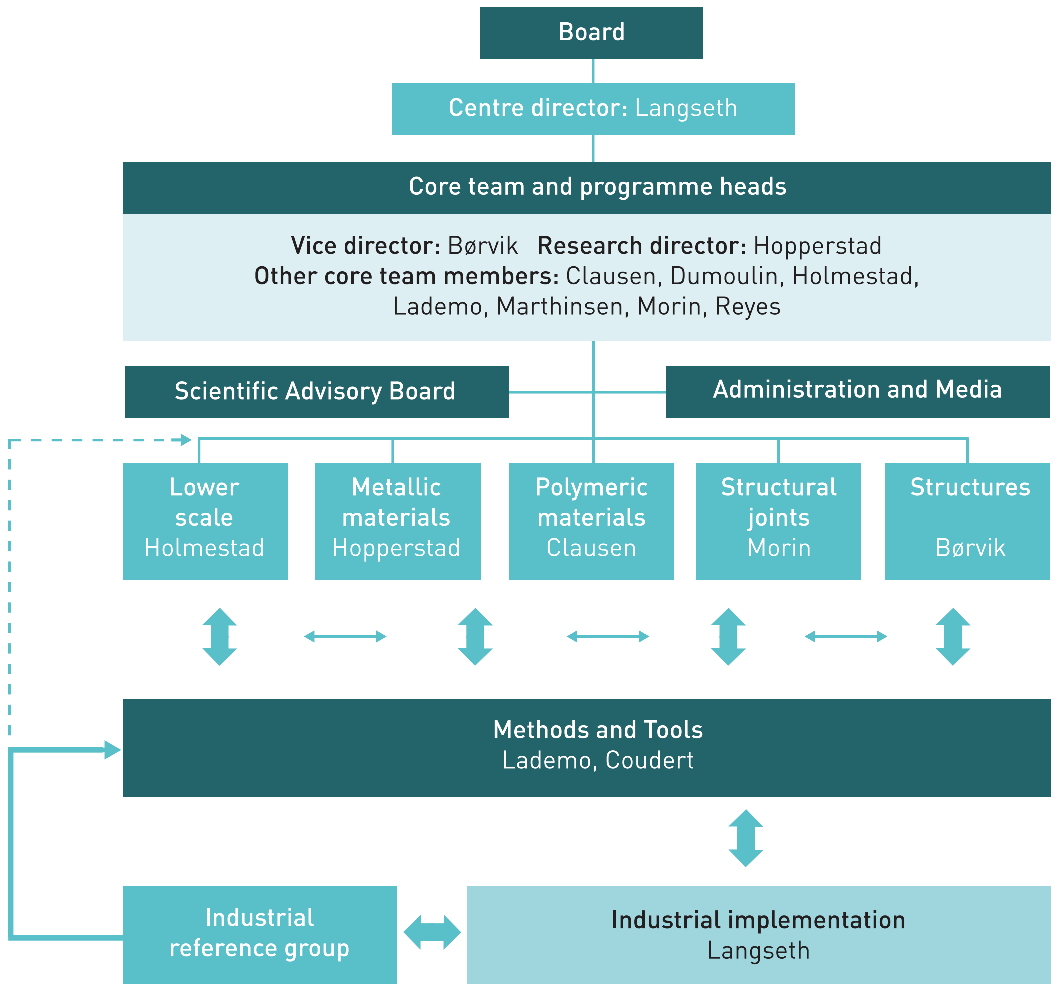


Figure 2: Structure of research, technology transfer and industrial implementation.

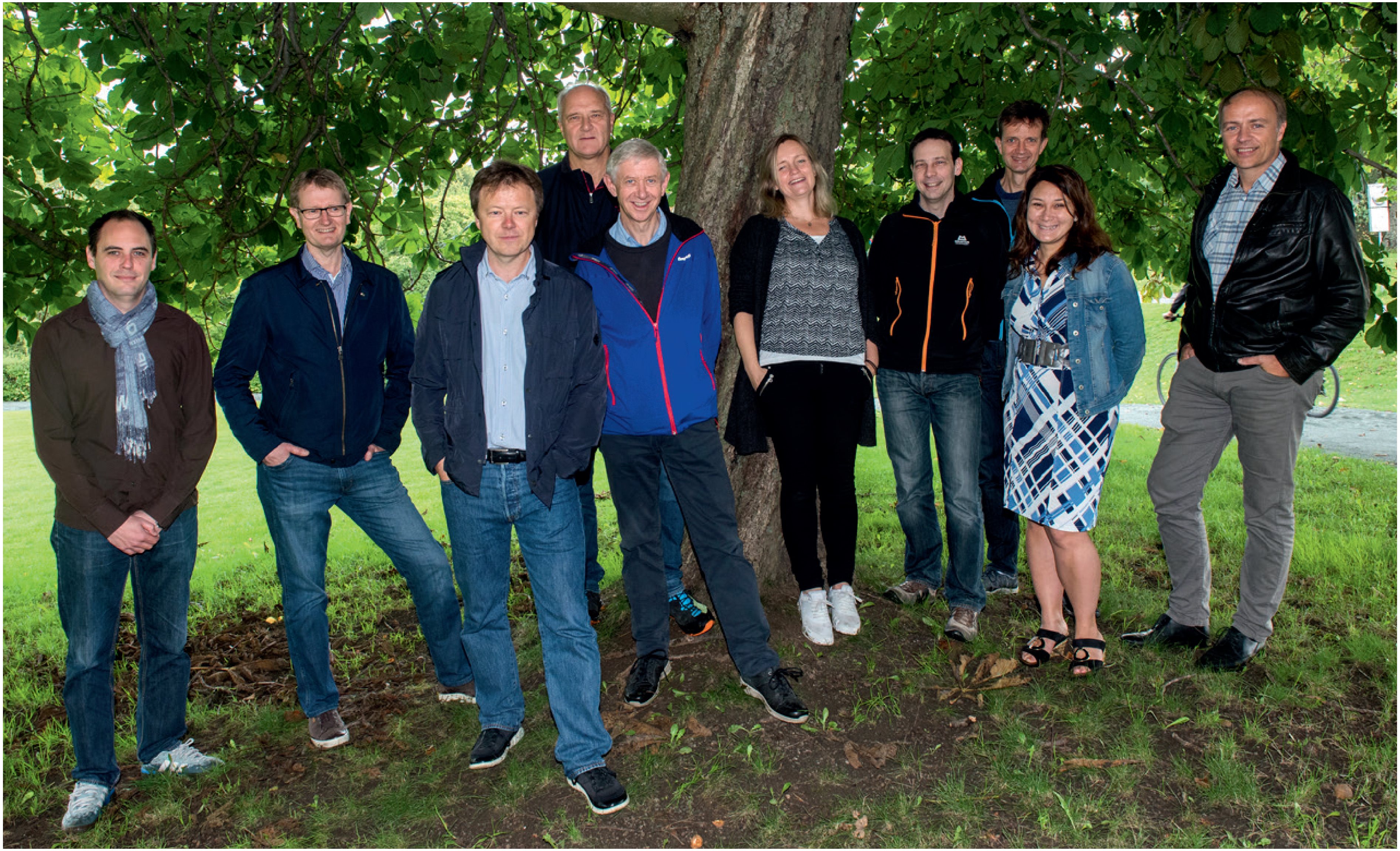
The activities in CASA will represent a step change for advanced structural analysis for industry and public enterprises as it is based on multidisciplinary and interdisciplinary research on different physical scales. The research methodology adopted to meet the overall objective is presented in Figure 1. As illustrated, a structure or product can be studied on different physical scales just like the modelling scales (there is also a time scale which reflects the duration of the physical events to be studied, but this is not shown in the figure). By using a top-down/bottom-up approach the main goal of the research will always be the final structure or product. In some cases, microstructural modelling or even modelling on atomic scale may be required to understand the underlying physical mechanisms of the observed material response to loading. However, for joints or components the behaviour may be sufficiently well understood on the continuum scale. In all cases, research at the Centre will be 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 and 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 and Tools Programme and the industrial use of the research and technology developed at the Centre for innovation.

RESEARCH ORGANIZATION



The overall management structure of the Centre consists of a Board comprising members from the consortium participants, Figure 3. 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 is in charge of the operation of the Centre, assisted by a core team. A Scientific Advisory Board of international experts provides 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 possible synergies. The Methods and Tools Programme is the main instrument to link the research programmes in the Centre and the Industrial implementation at the industrial partners. These activities are also led by programme heads. The Centre has a clear strategy for the management of intellectual property issues, including any assignment for commercialization or development and the distribution of any commercial returns.

Figure 3 : Structure of the organization in 2016.



Core team. *From left: David Morin, Odd Sture Hopperstad, Tore Børvik, Magnus Langseth, Knut Marthinsen, Randi Holmestad, Stéphane Dumoulin, Arild Holm Clausen, Aase Reyes and Odd-Geir Lademo.*

The Board

Asbjørn Rolstadås (Chair), NTNU
Anders Artelius, Benteler Aluminium Systems Norway AS
Duane Detwiler, Honda R&D Americas Inc.
Agnes Marie Horn, DNV GL AS
Håvar Ilstad, Statoil Petroleum AS
Anne Berte Jordal, Gassco AS
Andreas Koukal, Audi AG
Helge Langberg, Norwegian Defence Estates Agency
Øivind Mandt, Norwegian National Security Authority
Satoru Miyagano, Toyota Motor Europe
Kjartan Pedersen, Aker Solutions
Eva Petursson, SSAB
Thorsten Rolf, BMW Group
Rudie Spooren, SINTEF
Jan Strid, Sapa AB
Knut Syvertsen, Ministry of Local Government and Modernisation
Hans Erik Vatne, Hydro Aluminium AS
Gina Ytteborg, Norwegian Public Roads Administration

Scientific Advisory Board

Professor Ahmed Benallal, LMT-Cachan, 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

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 Materials and Chemistry
Stéphane Dumoulin, Research Scientist, SINTEF Materials and Chemistry
Randi Holmestad, Professor, Dept. of Physics, NTNU
Odd Sture Hopperstad, Professor, Dept. of Structural Engineering, NTNU
Odd-Geir Lademo*, Research Manager, SINTEF Materials and Chemistry
Knut Marthinsen, Professor, Dept. of Materials Science and Engineering, NTNU
David Morin, Associate Professor, Dept. of Structural Engineering, NTNU
Aase Gavina Reyes, Professor, Dept. of Structural Engineering, NTNU

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

Administrative and key personnel

Trond Auestad, Senior Engineer, Dept. of Structural Engineering, NTNU
Torodd Berstad, Researcher, Dept. of Structural Engineering, NTNU
Albert H. Collett, Communication Officer, Dept. of Structural Engineering, NTNU
Egil Fagerholt, Researcher, Dept. of Structural Engineering, NTNU
Peter Karlsaune, Project Coordinator, Dept. of Structural Engineering, NTNU
Laila Irene Larsen, Accountant, Dept. of Structural Engineering, NTNU
Tore Wisth, Staff Engineer, Dept. of Structural Engineering, NTNU

Partners

Host institution
NTNU

Research partner
SINTEF Materials and Chemistry

Industrial partners
Aker Solutions
Audi AG
Benteler Aluminium Systems Norway AS
BMW Group
DNV GL AS
Gassco AS
Honda R&D Americas Inc.
Hydro Aluminium AS
Ministry of Local Government and Modernisation
Norwegian Defence Estates Agency
Norwegian National Security Authority
Norwegian Public Roads Administration
Sapa AB
SSAB
Statoil Petroleum AS
Toyota Motor Europe

CASA's Scientific Advisory Board *had their first meeting under autumn leaves in October. From left: Professor John Hutchinson, Harvard University, USA, Professor Em. David Embury, McMaster University, Canada, Professor Ahmed Benallal, LMT-Cachan, France, Dr. Frank Schäfer, Ernst-Mach-Institut, Germany, Professor Jonas Faleskog, Royal Institute of Technology, Sweden and Professor Norman Fleck, University of Cambridge, UK.*

COOPERATION WITHIN THE CENTRE

The project description in the SFI application for CASA and discussions with the industrial partners through the autumn of 2015 formed the basis for the annual work plans for 2016. Further discussions took place in the technical meetings in the research programmes in 2016 in order to finalize work plans for 2017 and the following years.

CASA has put extra effort into the implementation work in 2016. An Industrial Reference Group (IRG) was established on 1 March 2016 and a second meeting took place in November in conjunction with the Centre's annual seminar and Board meeting. Each industrial partner has one member in the IRG and its mandate is to give advice on how implementation should be facilitated and evaluate the implementation work at each partner.

Scientists from NTNU, SINTEF and PhD candidates at NTNU have been the main contributors in the research work, while the industrial partners have participated with their defined in-kind contribution. DNV GL AS, Norwegian Public Roads Administration and Hydro Aluminium AS are sponsoring one Adjunct Professor position each at the Department of Structural Engineering, NTNU. This ensures a link between industry and the PhD and master's students at CASA. The Core Team has a meeting every week led by the Centre Director. Every two weeks the group has had a seminar on a variety of issues in order to spread knowledge and information in the Centre's research group. The cooperation with the industrial partners has been through telephone meetings, technical meetings and seminars. The Centre's annual seminar and Board meeting was held at Radisson Blu Royal Garden Hotel in Trondheim on 16 –17 November.

The Board of CASA comprises one member from each of the 18 partners in the Centre. NTNU's representative is Chairman of the Board. The Board had two meetings in 2016: a telephone meeting on 22 June and a meeting in Trondheim on 17 November.

Participants at the SIMLab Tool Box seminar in September.

INTERNATIONAL COOPERATION AND LEADING-EDGE RESEARCH

International cooperation is one of the success criteria defined by the Research Council of Norway for an SFI centre. Six of the industrial partners in CASA are from outside Norway. CASA also has strong interaction with universities and research organizations abroad. The key researchers in CASA all have an extensive international network. This is a result of many years of high quality research made visible through publication in peer-reviewed journals. In addition, three of the Centre's professors are editors of some of the main 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 has had cooperation with the following universities and research laboratories in 2016:

Ecole Normale Supérieure de Cachan/Laboratorie de Mécanique et Technologie (ENS/LMT), France; Federal University of Rio de Janeiro, Brazil; University of São Paulo, Brazil; Department of Materials Science and Engineering, University of Toyama, Japan; Department of Metallurgy and Ceramics Science, Tokyo Institute of Technology, Japan; IMPETUS Afea AB, Sweden; Joint Research Centre, Institute for the Protection and Security of the Citizen, Italy; Faculty of Engineering and the Environment, University of Southampton, UK; Purdue University, USA.

SFI CASA is a world-leading research centre and maintaining this position depends on receiving advice from the best. A Scientific Advisory Board of international experts has been appointed and held its first meeting in Trondheim on 26-27 October. Comprehensive presentations of the Centre's research programmes were given by the CASA's researchers. The Advisory Board also compiled a report that gave the Centre management feedback on the work done and recommendations for further improvements.

International cooperation is crucial for success. Here Trond Auestad (left) and Egil Fagerholt from SFI CASA receive colleagues Geovanio Lima, Marysilvia Costa and Aynor Ariza from the Federal University of Rio de Janeiro in Brazil in May. Photo: Albert H. Collett.

RESEARCH PROGRAMMES

Lower Scale

Head of Programme: Randi Holmestad

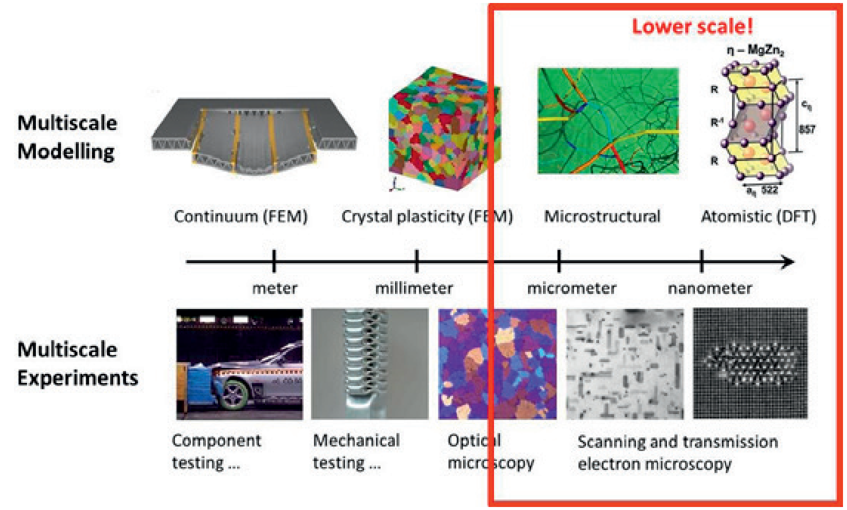


Figure 4: In a multiscale framework, the lower scale programme covers the micrometre and nanometre scales for modelling and experiments.

This programme concentrates on the lower length scales of materials, from the atomic up to micrometre scale. Thus, it will provide experimental and calculated input to the multiscale framework from the lower scale. This will provide constitutive models for microstructure evolution, strength and work hardening for metallic materials, such as aluminium and steels. It will also provide a foundation for the development of physically based models for crystal plasticity, continuum plasticity, damage and fracture.

The overall goal is to connect and coordinate the atomic and microscale frameworks connecting the models and the experiments at the different scales. The results will provide increased basic understanding of mechanical properties and deformation of metal structures in a multiscale framework (from the nano-scale to the complete structure). This will work as a basis for achieving improved models and will be used in both model developments and validations, Figure 4.

Four PhD students are working in the lower scale programme:

• PhD research by Emil Christiansen (Dept. of Physics, 2015-2019) is focused on the micro- and nanostructure characterization of deformed aluminium alloys using transmission electron microscopy (TEM). The objective is to investigate the underlying physical mechanisms of ductile fracture in age hardening aluminium alloys. In short, this PhD work is concerned with the interaction between dislocations and precipitation free zones (PFZs) and the evolvement of the microstructure as a function of strain. So far, he has studied how the microstructure in the PFZ of the AA6060 alloy changes as a function of deformation. His results will act as input to the different models used to describe deformation response and will be applied to verify and develop numerical models in the related SFI CASA projects.

• PhD student Christian Oen Paulsen (Dept. of Materials Science and Engineering, 2015–2019) is focusing his research on combining experimental work and modelling activities to describe the correlation between microstructure and mechanical properties in multiphase steel. He is performing a systematic, experimental study of local mechanical properties and in-situ testing using scanning electron microscopy (SEM), with the possibility of cooling the material to sub-zero temperatures. This gives input data for mathematical models for understanding and describing the performance of heterogeneous materials based on microstructure information. The experimental tests are combined with digital image correlation to obtain detailed information about the local deformation.

• The PhD project of Jonas Frafjord (Dept. of Physics, 2016-2020) will couple atomistic simulations, e.g. density functional theory, and meso-scale methods, e.g. dislocation dynamics. The goal is to provide a more fundamental understanding of mechanical properties and use this to improve and calibrate models on a continuum scale. He will study the effect of solute atoms and hardening precipitates, and how these affect initial yielding and hardening under different conditions. Initially, Jonas has started to study how solute-dislocation interactions affect the yield stress and he is developing a method that predicts from first principle the influence of hydrostatic pressure on the solute strengthening of various alloying elements (such as Mg, Si, Fe and Mn) in aluminium.

• PhD student Jianbin Xu (Dept. of Materials Science and Engineering, 2016-2019) is studying the Portevin–Le Chatelier (PLC) effect, which describes the serrated yielding some materials exhibit as they undergo plastic deformation, resulting in early shear failure and thus reduced formability. The effect is associated with dynamic strain aging or interaction between solute atoms and matrix dislocations in strained metallic alloys. Initially, Jianbin has started to familiarize himself with existing modelling approaches for work hardening and flow stress to describe solid solution strengthening and the PLC effect in aluminium alloys. He will continue with experimental characterization to provide a basis for testing, validation and further improvement of existing modelling tools.

Metallic Materials

Head of Programme: Odd Sture Hopperstad

Figure 5: Mesh of the 3D aggregate made of 1200 grains.

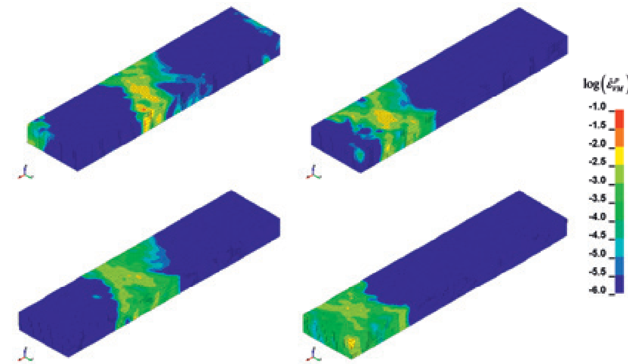


Figure 6: Contour plots of von Mises plastic strain rate (log scale) from the simulation with initial rate of 1.0×10^{-2} s^{-1}.

As they represent in an average sense the microstructural rearrangements of the material, constitutive models describe the stress and internal variables as functions of the strain, strain rate and temperature. In large-scale simulations of structures, the framework of continuum thermo-mechanics is typically adopted to formulate the constitutive models, while thermo-mechanical testing is used to identify the model parameters. Advanced constitutive models, including plastic anisotropy, non-linear isotropic and kinematic hardening, strain-rate and temperature dependence, damage evolution and failure, tend to have a large number of model parameters.

In close collaboration with the Lower Scale Programme, this research programme applies multiscale methods to develop validated constitutive models for large-scale simulations of metal structures. Thus, the need for calibration of the constitutive models against thermo-mechanical tests is reduced and the prediction accuracy of the models is increased with respect to properties that are not always easily measured by testing. Qualitative and quantitative descriptions at different length scales are closely accompanied by well-designed experiments at the relevant length scales for the phenomena of interest (from the nanoscale to the complete structure). This provides a basis for achieving improved understanding, model development and model validation. As the quantum, atomistic and nanoscales are covered by the Lower Scale Programme, this programme deals with crystal plasticity and continuum plasticity at the micro-, meso- and macroscales.

The main themes in the research activities in 2016 have been:

- Micromechanical modelling of ductile fracture in aluminium alloys (PhD, Lars Edvard Bryhni Dæhli)
- Ductile fracture of aluminium alloys at low stress triaxiality: an experimental and numerical study (PhD, Bjørn Håkon Frodal)
- Micromechanical modelling and simulation of steel materials (PhD, Sondre Bergo)
- Modelling and simulation of localization, damage and fracture in age-hardening aluminium alloys (Principal investigator S. Dumoulin)
- Micromechanical modelling and simulation of dual-phase steels (Principal investigator A. Saai)
- Strain gradient plasticity (Principal investigator T. Berstad)

In addition to researchers at SINTEF Materials & Chemistry and professors at NTNU, three PhD candidates are linked to the activities in the research programme, namely Lars Edvard Bryhni Dæhli (2013-2017), Bjørn Håkon Frodal (2015-2019) and Sondre Bergo (2016-2020).

As an example of the research activities, the SIMLab Crystal Mechanics Model (SCMM) has been extended in 2016 by including dynamic strain aging, which leads to jerky plastic flow in some aluminium alloys and inhomogeneous deformation with propagating localization bands. We can now model this behaviour using the crystal plasticity finite element method where grains are discretized into elements. Figure 5 shows a finite element model of a tensile test in which the grains are discretized, while the simulated propagating localization bands under tensile loading are illustrated in Figure 6.

Polymeric Materials

Head of Programme: Arild Holm Clausen

1. Specimen *n*
2. Specimen *n*+1
3. Camera 1
4. Camera 2
5. IR camera
6. LN2 container
7. PC chamber
8. Table top fan

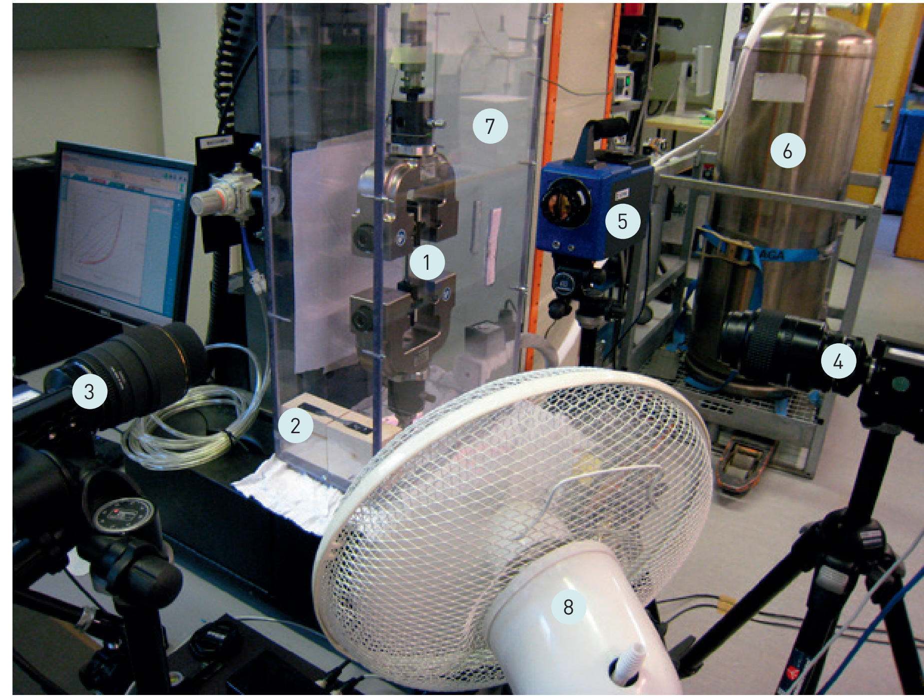


Figure 7: Experimental set-up for material tests at low temperatures.

Polymers comprise a wide range of natural and synthetic materials. The demand for polymers has increased considerably during the last few decades. Applications include safety-related parts in cars, coatings, thermal insulation in offshore components, seals and inter-glass layers in laminated windows. The finite element method has only rather recently become a relevant tool in the design process of parts made of polymers. Therefore, constitutive models for such materials are less mature than for metals. Prediction of fracture is also a topic of interest for research and industry. Knowledge about the physical mechanisms governing the thermo-mechanical behaviour is of utmost importance for successful development of material models. The main objective of the Polymeric Materials research programme is to develop and improve material models representing the thermo-mechanical response up to fracture for polymers. 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. Actual materials include commodity thermoplastics (like PE and PP, commonly reinforced with small mineral and/or rubber particles), fibre-reinforced thermoplastics, elastomers and foams made of polymers.

The large-strain response of ductile thermoplastics has been the topic of Marius Andersen's PhD project. He finished his thesis in early 2016. It contains work on the development of robust methods for experimental characterization as well as a constitutive model that is able to represent the stress-strain curve at different strain rates and temperatures. Directly financed by Aker Solutions in an affiliated project, Arne Ilseng also delivered his PhD thesis in 2016. His topic was the behaviour of elastomers at different temperatures. He applied a transparent chamber made of polycarbonate, see Figure 7, in his research. It was connected to a supply of liquid nitrogen, allowing for material testing at low temperatures in combination with instrumentation involving digital cameras. This chamber has also been applied in other studies.

Ongoing PhD projects comprise Petter Henrik Holmstrøm who is working on the modelling of fibre-reinforced thermoplastics, and Sindre Olufsen, who is studying ductile failure. In addition to mechanical tests, computer tomography (CT) is an important tool in both projects in order to improve the understanding of the deformation mechanisms to capture in the material models. New PhD candidates from August 2016 are Jon Eide Pettersen and Daniel Morton, who are respectively working on viscoelastic behaviour and foams.

The interaction with the industrial partners engaged in the Polymeric Materials programme is maintained through annual technical meetings. One such meeting was arranged in Trondheim in November 2016, and gathered Audi, BMW, DNV GL, Statoil and Toyota. The partners addressed their research needs at these meetings, and provided valuable advice for future research activities.

Structural Joints

Head of Programme: David Morin

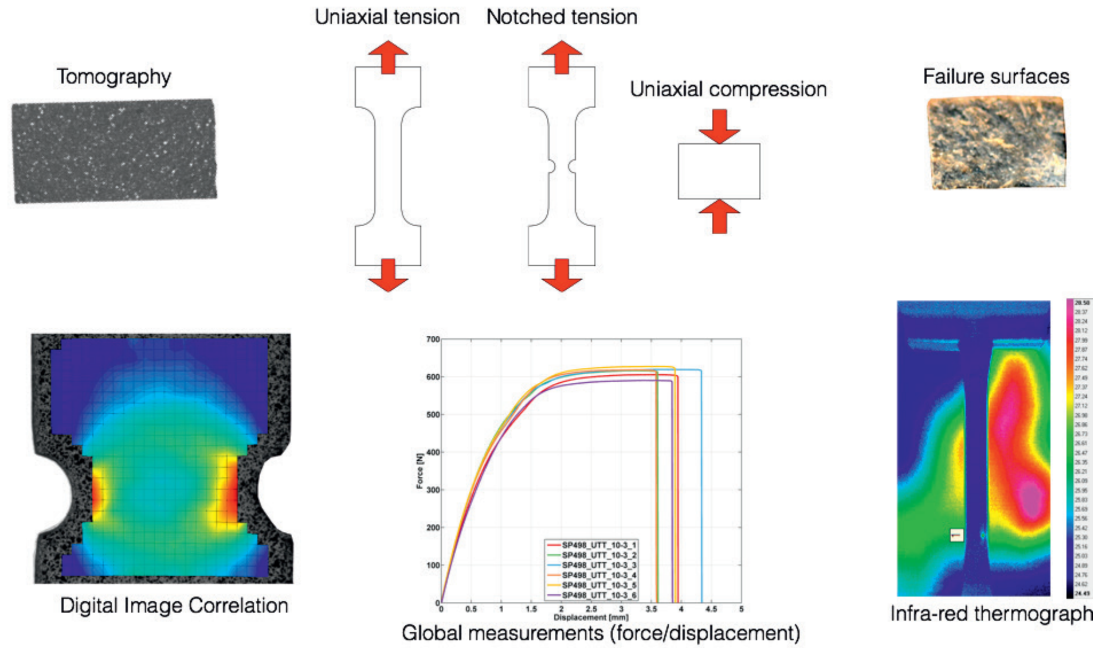


Figure 8: Characterization procedure of structural adhesives.

The need for multi-material structures in the automotive, offshore and physical security industries is becoming increasingly important to meet the requirements in terms of performance and weight reduction of their products. Often, the behaviour of a structure is strongly linked to its connections and its capacity to sustain and transfer the applied load to its different members. In this perspective, the design of multi-material structures using numerical simulations has to take into account how the connections will behave and fail. Today, large shell elements are used for computational efficiency which hampers an accurate representation of the connections and their failure modes due to a poor discretization of these complex problems.

The aim of this research programme is to provide macroscopic models for multi-material connections which are based on a fundamental understanding of the structural joints. These models should be industry-friendly in terms of computational time as well as the calibration cost. Here, multi-material connections involve a combination of aluminium, steel and fibre reinforced polymers.

The objective of the programme is fulfilled by using a multiscale testing and modelling strategy. This strategy involves testing at different scales from the material within the connector, through single connector tests, to the final component level. Each of these testing levels is important to gain a fundamental understanding of the connections of interest. In terms of numerical modelling, mesoscopic models where the connections are represented by solid elements will be employed to increase knowledge of the behaviour and failure of structural joints. However, macroscopic models are the final outcome of the programme.

In 2016, a PhD project was launched with the PhD candidate Matthias Reil, who is funded by BMW and CASA. The topic of his work is joining of steel and aluminium using structural bonding and self-piercing rivets. His project will have strong focus on the virtual testing of these connections and the calibration of industry-friendly macroscopic models.

Moreover, three other PhD students were involved in the research programme in 2016:

- Johan Kolstø Sønstabø is working on the behaviour and modelling of Flow-Drill Screw connections in aluminium structures. (Funded by Honda Americas, started in 2013.)
- Erik Løhre Grimsmo is working on the behaviour and modelling of bolted and welded connections. (Funded by SFI SIMLab, started in 2013.)
- John Fredrick Berntsen is working on the behaviour and modelling of multi-material connections. (Funded by SFI CASA, started in 2015.)

In 2016, PhD candidates Matthias Reil and John Fredrick Berntsen characterized their respective structural adhesives using the same procedure as that developed by the Polymeric Materials research programme, Figure 8. During the spring 2016, PhD candidate Johan Kolstø Sønstabø spent three months at Honda R&D Americas to implement some of the results from his PhD into an industrial environment.

Structures

Head of Programme: Tore Børvik

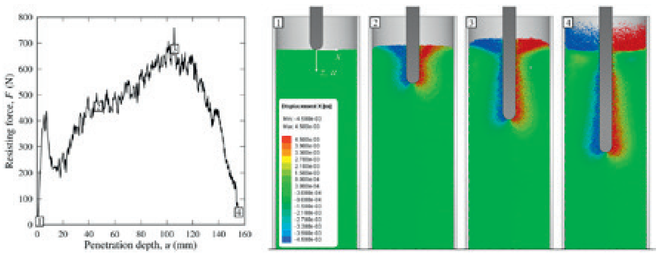


Figure 9: Numerical simulation of a hemispherical-nose projectile penetrating a sand target at an impact velocity of 5 m/s applying the discrete particle method (DPM) in the IMPETUS Afea solver.

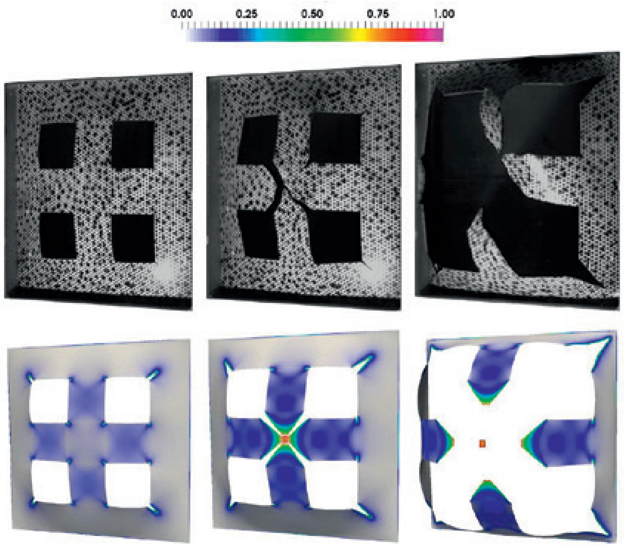


Figure 10: Comparison between high-speed camera images (top) and simulations with adaptive mesh refinement in EUROPLEXUS (bottom) from a blast-load experiment in SIMLab's shock-tube on a thin steel plate with pre-formed holes.

Design against accidental loads, such as explosions, impacts and collisions, has become increasingly important for a number of engineering and industrial applications. In order to meet the challenges posed by such complex loading conditions, product development and structural analysis are often carried out in virtual environments using the finite element method to achieve safer and more cost-effective designs. The long-term goal of this research programme is to improve the survivability of people and vital infrastructure to a given threat. It is important to realize that the protective structure is the last layer of defence against a threat when all other protective measures have failed. It is thus of utmost importance that such structures are designed and validated on a sound theoretical and experimental basis. To do so, accurate, efficient and robust constitutive models and solution techniques used in a multiscale modelling context are required. Further, new designs need to be validated through high-precision experiments involving advanced instrumentation such as three-dimensional digital image correlation for full-field displacement and strain measurements. Although much information can be obtained from laboratory tests, relying on such an approach would be too costly and inefficient. Computer-aided design, together with a strategy for material selection, optimization and well-selected validation tests, can significantly lower the cost and enhance the overall quality and efficiency of the required protection.

The main objective of this research programme is to develop and evaluate advanced computational tools and establish validated modelling guidelines for computer-aided design of safer and more cost-effective protective structures. Another objective is to replace phenomenological models by 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. This will be carried out in close collaboration with the other research programmes in CASA.

The main research activities in 2016 have been:

- Modelling and simulation of ballistic impact (PhD project, Jens Kristian Holmen).
- Behaviour and modelling of flexible structures subjected to blast loading (PhD project, Vegard Aune).
- Fragmentation of window glasses exposed to blast loading (PhD project, Karoline Osnes).
- Impact against coated and uncoated offshore steel pipes (PhD project, Ole Vestrum).

The two first PhD projects are activities from SFI SIMLab, which are directly continued in SFI CASA. Jens Kristian Holmen defended his PhD thesis in September 2016, while Vegard Aune will defend his PhD thesis in May 2017. Jens Kristian Holmen is employed as postdoc in CASA. Karoline Osnes' PhD project started in August 2015, while Ole Vestrum started his PhD project in January 2016. In addition, a concurrent research activity on blast-loaded concrete plates conducted by postdoc Martin Kristoffersen (financed by the research project "Ferry-free coastal route E39" hosted by the Norwegian Public Roads Administration) has been linked to the research in Structures. Examples from the PhD projects of Jens Kristian Holmen and Vegard Aune are shown in Figure 9 and Figure 10, respectively.

TECHNOLOGY TRANSFER

Methods and Tools

Heads of Programme: Odd-Geir Lademo and Térence Coudert

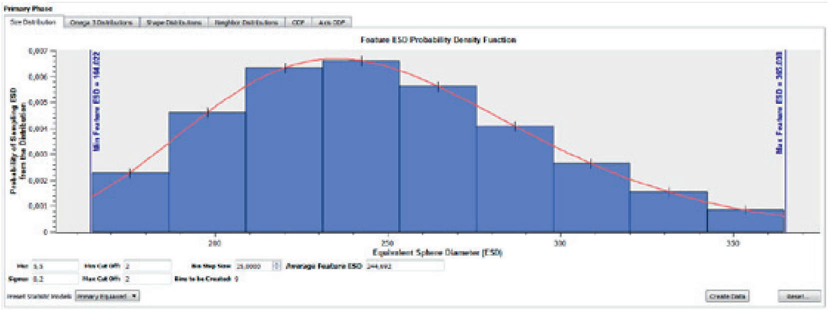


Figure 11: DREAM.3D software: plugin interface to control the grain distribution.

The Methods and Tools Programme represents the main instrument to link *Basic research* at the Centre to Industrial implementation at the industrial partners. The SIMLab Toolbox is a synthesis of the research results. It supports and guides the user to the necessary steps to build a reliable finite element model for advanced structural analysis, such as selecting the suitable material model, processing experimental data, calibrating and optimizing the material model parameters.

Two main tasks have been performed during 2016. One was to improve the existing SIMLab Toolbox and the other, in close collaboration with the Metallic Materials Programme, was to develop and introduce new tools for multiscale modelling.

Components in the SIMLab Model Library (SML) have been released for the partners: SMM for Metals and SPM for Polymers. Other developments have been carried out for the SCMM (Crystal Mechanics), the SCZM (Cohesive Zone) and for the SPPM (Porous Plasticity) and some of them will be released in 2017. The development work is performed in a professional software development arena '*code.sintef.no*', which enables team-oriented development through proper systems for documentation, version control, issue tracking, and continuous feature testing. Using the latter, the SMM and SCMM are tested against well-known simulation cases in an automated procedure using LS DYNA and ABAQUS. This enables the developer to raise issues early when a change is made in the user material subroutine. The model calibration toolbox (e.g. MatPrePost) provides identification procedures for the SMM and the SPM. As other material models could be supported in the near future (e.g. Johnson-Cook model), the development of a material card converter has been initiated.
Several tools are needed at different scales to assist the research in the various programmes. In 2016, focus has been given to generating representative volume elements for FEA using the Crystal Mechanics model. The team has selected an open source software DREAM.3D and developed plugins that fit the needs of the Centre. As shown in Figure 11, DREAM.3D is modular software package that allows users to reconstruct, instantiate, quantify, mesh, handle and visualize multidimensional, multimodal data. It was originally designed to analyse microstructure data coming from EBSD observations, and can generate equivalent material structures (as shown in Figure 12) from statistics that are synthetic or are extracted from real data. A series of filters have been developed to allow the generation of 3D hexa-based and 2D shell-based meshes, with corresponding material cards for the SCMM. The generated input files are for LS DYNA or ABAQUS.

During a multiscale modelling approach, several solvers and data sets are used. Since the solvers may run on different platforms and a variety of machines, the development team has tried to find a solution to obtain an efficient mechanism for storing and exchanging data. This problem is well-known in software development and some solutions already exist (e.g. SOFT5 in EU project NanoSim).

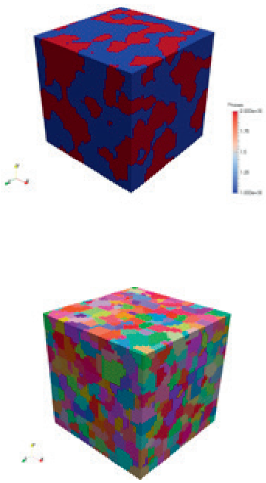


Figure 12: Example of generated microstructure.

Industrial Implementation

Head of Programme: Magnus Langseth

In order to strengthen the industrial implementation of the research and cooperation between the partners, an industrial reference group has been established where there is one expert from each partner. The mandate of the industrial reference group states that an annual report has to be presented to the SFI CASA Board about how the implementation is carried out.

A survey has been completed to facilitate the interaction between the research group and the partners with respect to implementation. The partners were asked to define what implementation means, how implementation was carried out and how the partners disseminated the obtained results in their own organization. In addition, the partners have been asked to define what is within and beyond the scope of the Centre and how they define the characteristics of an active partner or a partner who only follows the research activities.

The answers from the partners show that implementation is defined as short- and long-term activities. In a short-term perspective, a key issue is the training of the partners to use the tools that are developed, whereas for long-term activities they expect that the technology will be implemented into their daily processes. Implementation in such processes means for instance that the models developed are incorporated into the commercial solvers used by the partners and that the models are robust, accurate, user friendly and well documented. Figure 13 illustrates how Audi plan the implementation of the SIMLab Tool Box in their organization and how this is coupled with a validation strategy.

Figure 14 shows that all implementation in the Centre starts with the proof of technology through master's projects at NTNU linked to the Centre's activities. The partners launch the topic of the master's projects through the industrial reference group. At a later stage, an internal evaluation of the technology is carried out by the partners hosting master's students. PhD candidates can also contribute here. The proof of technology and the internal evaluation are within the scope of the Centre, whereas concurrent projects are outside. Figure 14 also illustrates that all implementation is followed by training courses at NTNU or at the partners. These courses are linked to a validation strategy on several scales.

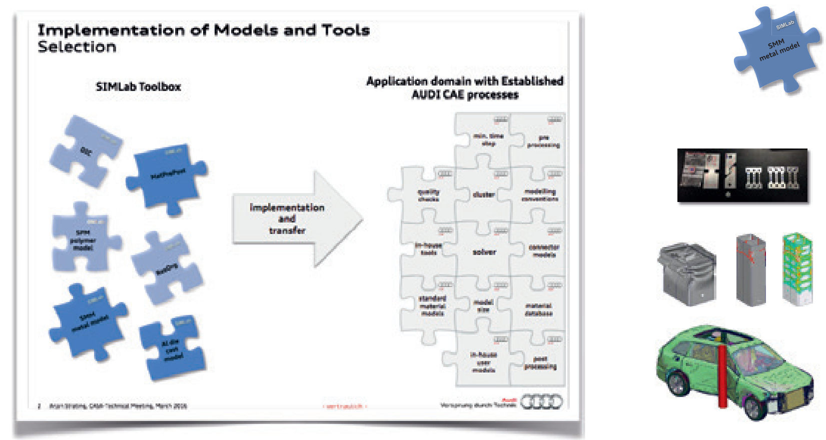


Figure 13: Implementation at Audi.

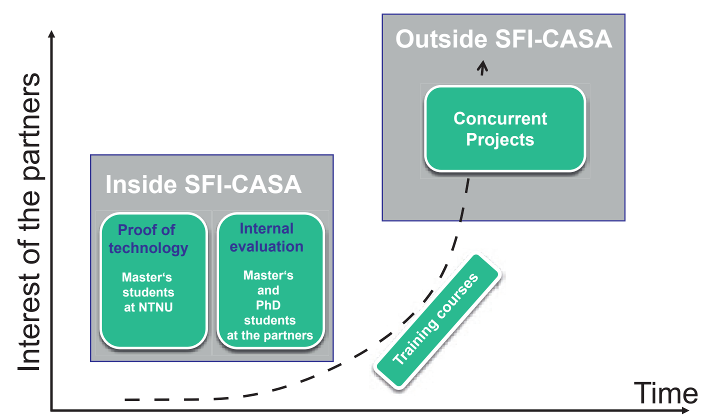
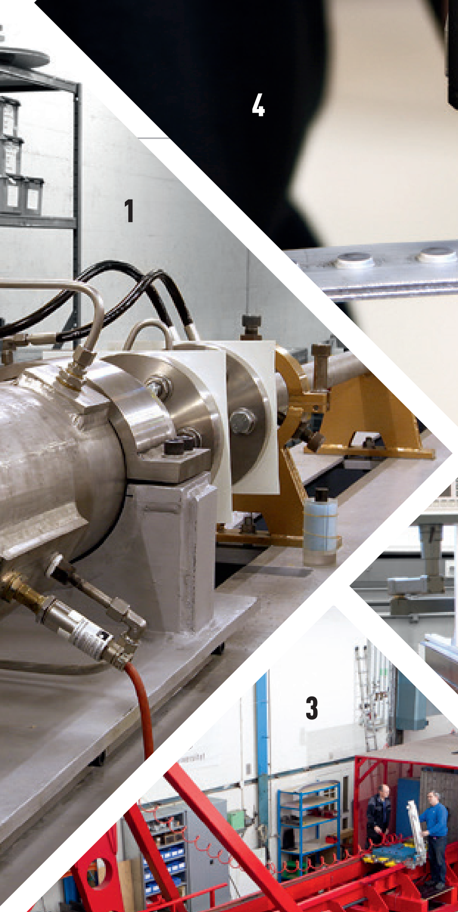
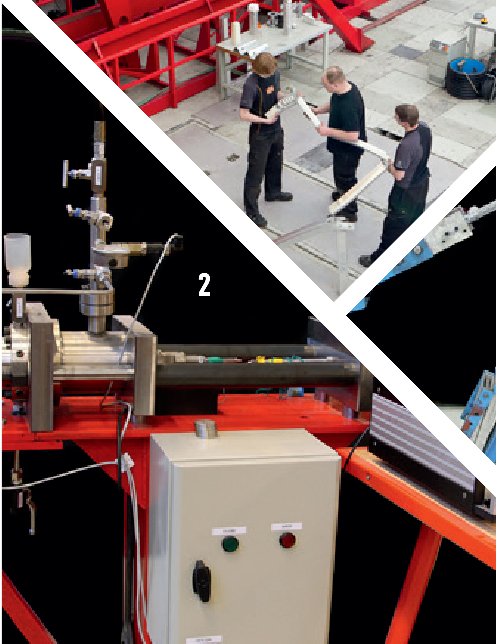


Figure 14: Proof of technology, internal evaluation and concurrent projects.





Photos 1, 2, 4, 5, 6 and 7: Melinda Gaal
Photos 3 and 8 – 10 and 12: Ole Morten Melgård

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. Please go to our website to read more about the Centre's laboratories: www.ntnu.edu/casa

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.

Hydro-pneumatic machine (HPM) (2)
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) (3)
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 that is connected to a hydraulic/pneumatic actuator system. The maximum energy delivered to the trolley is approximately 500 kJ. At present the mass of the trolley is in the range between 800 and 1500 kg, giving a maximum velocity between 35 m/s and 26 m/s.

Self-piercing riveting machine (4)
In this machine self-piercing riveting can be carried out of sheets under industrial conditions.

Sheet metal forming machine (BUP) (5)
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.

Split-Hopkinson tension bar (SHTB) (6)
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.

Stretch bending rig (7)
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.

Droptower impact system (8)

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 from 2-70 kg and gives an impact velocity in the range 0.8-24 m/s. All tests can be carried out with an instrumented nose which gives the impact force as a function of time.

Split-Hopkinson pressure bar (SHPB) (9)

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.

Shock tube facility (10)

The SIMLab Shock Tube Facility consists of a long tube and a tank. 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 x 0.3 m. Threaded holes in the tube floor enable mounting of test specimens in the test section, and windows in the test section and the dump tank allow high-speed cameras to investigate the structural response during an experiment.

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 have 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.

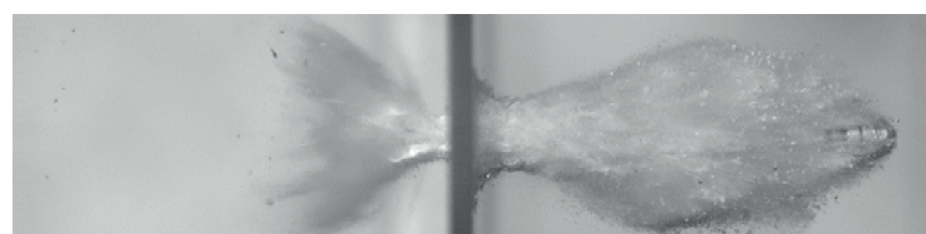
Cameras

CASA has a FLIR SC7500 infrared camera that can convert infrared radiation to a visual image that depicts thermal variations across an object or scene. Thus it can be used to measure the surface temperature of a specimen under inelastic deformations. With a resolution of 320x256 pixels the maximum frame rate is 380 per second, while at a resolution of 48x4 pixels the maximum frame rate is 31 800 per second (FPS). During impact testing of materials and structures, the events are recorded using high-speed cameras. The research group purchased a new Kirana-05M camera in 2016 with a maximum frame rate of 5 000 000 FPS, allowing detailed studies of crack propagation. In addition the research group has 4 more high-speed cameras and several cameras for Digital Image Correlation measurements.

Portable measuring arm and 3D printer

In addition to the new high-speed camera mentioned above, a portable measuring arm for 3D scanning and a 3D printer were acquired in 2016. The new equipment further improves the connection between physical testing and numerical analyses.

The picture shows a test where the Phantom V1610 high-speed camera has been used. A 7 mm laminated safety glass is hit by a 7.62 calibre lead bullet at a speed of 800 m/s. The camera is set to a frame rate of 60 000 FPS and exposure time 0.452 µs.



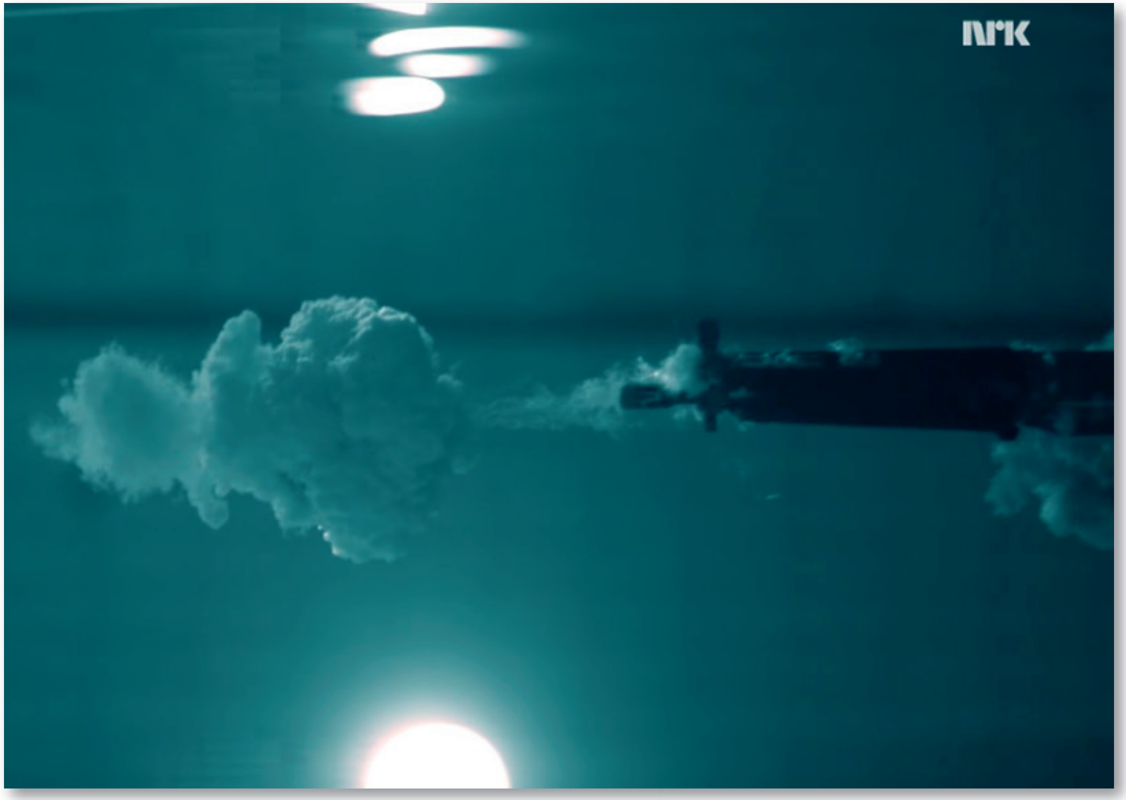
Media strategy
CASA aims at a media strategy for popular science presentations of its research activities in magazines, newspapers, on television, radio and the web. It is also an aim to make female researchers particularly visible in order to recruit women fellowship holders and contribute to a more even gender balance in this research field. The popularized part of this report is an example of how these strategies are carried out. The articles have also been published in our monthly newsletter (see below) and on the blog www.ntnutechzone.no.

SFI CASA newsletter
As part of the media strategy SFI CASA has a monthly newsletter. The newsletter is sent out to partners, contacts and other people in CASA's social and professional network and to professionally interested parts of the media. The newsletter presents both research news and in-depth interviews with key personnel working with CASA. The newsletter is published at: http://sfi-casa.no/ and anyone can subscribe to the monthly newsletter sent out by email.

Seminar on public security
CASA invited relevant public authorities to a seminar on physical security on 19 August 2016. The Norwegian state secretary for the Minister of Justice and Public Security, Gjermund Hagesæter and Senior Advisor May-Kristin Ensrud attended and contributed with a presentation of their research strategy. In addition representatives from the Norwegian National Security Authority, The Ministry of Local Government and Modernisation and the Norwegian Police Security Service were present.

Presentation video
In November 2015, CASA decided to make a presentation video. A significant number of the staff was involved in the planning and production throughout 2016. The result and reception will be presented in next year's annual report.

CASA in the media
CASA Senior Engineer Trond Auestad helped the National Norwegian broadcaster NRK in the production of a popular science program called Putting your life at risk (Med livet som innsats). Trond Auestad used one of CASA's Phantom cameras to film underwater testing with a rifle gun. The programme was broadcast on 24 January 2016.




NOU Norges offentlige utredninger 2016: 3

Ved et vendepunkt:
Fra ressursøkonomi
til kunnskapsøkonomi

Produktivitetskommisjonens andre rapport


TU ☰ INNHOLD Ledige jobber TU Event TU Ekstra Logg inn

FERJEFRI E39

Eksplosjonene i det 25 meter lange stålrøret blir viktige hvis Norge skal bygge verdens første rørbru

AV: MARI GISVOLD GARATHUN | SAMFERDSEL | PUBLISERT: 8. JUNI 2016 - 20:02

Facebook 0 Twitter

For å lære mer om hvordan man kan beskytte bygg og konstruksjoner mot bomber og terrorangrep, har forskere og studenter ved SIMLab på NTNU bygget ett 25 meter langt stålrør.

Nå er forsøkene i full gang, og forskerne i full gang med å teste hvordan glass, metall, betong og andre materialer reagerer på eksplosjoner, skriver Gemini.no.

TU JOBB

VVS-ingeniør - drift, v...

10 stillinger som sen...


NYHETER

» Planlegging av nytt regjeringskvartal

Kunnskap fra NTNU er viktig når staten bygger nytt regjeringskvartal. Sikkerhetsmyndighetene har besøkt NTNU for å få vite hva forskerne kan om bygningsmaterialer og eksplosjoner.

Regjeringsfolk studerer eksplosjoner hos NTNU

The research group SIMLab is mentioned as an example of a world leading research centre in an Official Norwegian Report on the need for readjustments in the Norwegian economy.

The Shock tube facility and CASA's concurrent project on submerged road tunnels were the topics in an article in the weekly technical magazine Teknisk Ukeblad on 8 June 2016.

The local newspaper Adresseavisen wrote about the visit from Gjermund Hagesæter, State Secretary for the Minister of Justice and Public Security on 23 August.

Guest lectures at SFI CASA

Professor Ahmed Benallal from LMT Cachan, France, stayed at CASA from 12 to 21 April. On 20 April he gave a lecture with the title *On the structure of constitutive equations for ductile porous solids with complex matrix behavior.*

Professor Marysilvia Costa from the Federal University of Rio de Janeiro, Brazil, visited CASA in the period 9-13 May. She presented her hometown, university and research on 12 May with a lecture titled *Brazil, Olympics and Polymers.*

Associate Professor Peter Pavlov from the University of Architecture, Civil Engineering and Geodesy (UACEG) in Sofia, Bulgaria visited SFI CASA from 9 to 13 May. He gave a guest lecture on 12 May entitled *From the Real Construction to the Experimental Set.*

Department director Christian Fredrik Horst at the Ministry of Local Government and Modernisation gave a talk on 23 June with the title *The New Government Headquarters (SOS (Sikkerhet Og samarbeid) – Nytt regjeringskvartal.*

Professor Fabrice Pierron from University of Southampton, UK held a guest lecture with the title *The Virtual Fields Method and applications to high strain rate identification* on 28 June.

Professor Wayne Chen from Purdue University, USA held a guest lecture on 5 September. His lecture had the title *In Situ Visualization of Dynamic Damage Evolution in Materials under Impact Loading.*

On 9 November Professor Leon Govaert from TU Eindhoven, The Netherlands gave a talk with the topic *Current options for fast evaluation of the long-term performance of load-bearing thermoplastics.*

Research visits abroad by CASA staff

PhD candidate Johan Kolstø Sønstabø stayed at CASA partner Honda R&D Americas from April to June 2016.

Research visits at CASA

Professor Ahmed Benallal from LMT-Cachan, France, stayed at CASA from 12 to 21 April.

Professor Marysilvia Costa from the Federal University of Rio de Janeiro, Brazil, visited CASA from 9 to 13 May.

MSc student Victor Lauvaux from ENSA ParisTech, France, visited CASA from May to June 2016.

MSc student Roy Snellen from TU Eindhoven, The Netherlands, stayed at CASA in the period August-November 2016.

Concurrent projects

Fundamental studies of materials' behaviour in future cold climate applications (SMACC) (2013-2018): NTNU and SINTEF are involved in this joint industry project. SINTEF is the project host. SIMLab is involved in the project with a PhD candidate working on the behaviour and modelling of thermoplastics at low temperatures.

Joint research project with Honda R&D Americas (2013-2017): The objective of the project is to model the behaviour and failure of flow drilling screws submitted to crash loadings. One PhD candidate is working on the project supervised by personnel from the Centre.

Alumast (2015-2017): NTNU is one of several partners in a consortium working on aluminium power pylons. A post doc at SIMLab is working on the project.

Microstructure based modelling of ductile fracture in aluminium alloys, FractAl (2015-2050): 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 from LMT Cachan France and Jonas Faleskog from the Royal Institute of Technology in Sweden.

Behaviour and modelling of elastomers subjected to a wide range of pressures and temperatures (2013-2016): Aker Solutions funded this project under the industrial PhD scheme supported by the Research Council of Norway. One PhD candidate has worked on this project supervised by personnel from NTNU's Department of Structural Engineering. The PhD candidate defended the thesis on 8 November 2016

Ferry-free coastal route E39 (2015-2017): The Norwegian Public Roads Administration heads an investigation of the possibilities for a ferry-free coastal route along the western coastline of Norway. The project funds a post doctoral research fellow who is working with submerged floating tunnels subjected to internal blast loading.

Fundamentals of intergranular corrosion in aluminium alloys (FICAL) (2015-2020): FICAL is a five-year competence-building project with funding from The Research Council of Norway and industrial partners. This project aims at establishing a new fundamental understanding of the mechanisms of intergranular corrosion (IGC) susceptibility. Partners in this project include NTNU, SINTEF, Hydro, Sapa and Benteler.

Aluminium alloys with mechanical properties and electrical conductivity at elevated temperatures (AMPERE) (2015-2020): AMPERE is a five-year competence-building project with funding from The Research Council of Norway and industrial partners. The objective for the project is to find an optimal combination of mechanical properties and electrical conductivity in aluminium alloys at elevated temperatures. Partners in AMPERE are NTNU, Hydro and Sapa.

Some of the concurrent projects are further described in the "Don't Read This"-article in the "Stories & Profiles" part of this report.

PERSONNEL

PhD candidates and post docs. *From left: Jon Eide Pettersen, Arne Ilseng, Johan Kolstø Sønstabø, Lars Edvard Dæhli, Emil Christiansen, Matthias Reil, Jianbin Xu, Petter Henrik Holmstrøm, Sindre Olufsen, Bjørn Håkon Frodal, John Fredrick Berntsen, Ole Vestrum, Marius Andersen, Sondre Bergo, Daniel Morton, Karoline Osnes, Henrik Granum, Jens Kristian Holmen, Jonas Frafjord, Christian Oen Paulsen, Vegard Aune, Joakim Johnsen and Susanne Thomesen.*

PhD candidates and post docs

PhD candidates with funding from SFI CASA

NAME	START	PLANNED EXAM	PROGRAMME	NATIONALITY	GENDER M/F
John Fredrick Berntsen*	2015	2019	Structural Joints	Norwegian	M
Emil Christiansen*	2015	2019	Lower Scale	Norwegian	M
Bjørn Håkon Frodal*	2015	2019	Metallic Materials	Norwegian	M
Sindre Olufsen*	2015	2019	Polymeric Materials	Norwegian	M
Karoline Osnes*	2015	2019	Structures	Norwegian	F
Christian Oen Paulsen**	2015	2019	Lower Scale	Norwegian	M
Sondre Bergo**	2016	2020	Metallic Materials	Norwegian	M
Jonas Frafjord*	2016	2020	Lower Scale	Norwegian	M
Daniel Morton**	2016	2020	Polymeric Materials	Norwegian	M
Jon Eide Pettersen*	2016	2020	Polymeric Materials	Norwegian	M
Matthias Reil**	2016	2019	Structural Joints	German	M
Ole Vestrum**	2016	2020	Structures	Norwegian	M
Jianbin Xu*	2016	2020	Lower Scale	Chinese	M

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

PhD candidates with funding from SFI SIMLab. The topics are highly relevant for SFI CASA

NAME	START	PLANNED EXAM	PROGRAMME	NATIONALITY	GENDER M/F
Marius Andersen*	2011	2016	Polymeric Materials	Norwegian	M
Vegard Aune	2012	2017	Structures	Norwegian	M
Lars Edvard Dæhli	2013	2017	Metallic Materials	Norwegian	M
Erik Løhre Grimsmo	2013	2017	Structural Joints	Norwegian	M
Jens Kristian Holmen*	2013	2016	Structures	Norwegian	M
Petter Henrik Holmstrøm	2013	2017	Polymeric Materials	Norwegian	M

*Thesis defended in 2016

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

NAME	START	END	PROJECT	NATIONALITY	GENDER M/F
Arne Ilseng*	2013	2016	Aker Solutions	Norwegian	M
Joakim Johnsen	2014	2017	SMACC	Norwegian	M
Mikhail Khadyko**	2015	2017	FractAl	Russian	M
Martin Kristoffersen**	2015	2017	E39	Norwegian	M
Johan Kolstø Sønstabø	2013	2017	Honda	Norwegian	M
Henrik Granum	2016	2020	FractAl	Norwegian	M
Susanne Thomesen	2016	2019	FractAl	Norwegian	F

*Thesis defended in 2016
**Post doc

After a year and a half, CASA's staff is still in the early stages of the eight-year run.

Recruitment

Seven PhD candidates started at CASA in 2016 and another two PhD candidates started on concurrent projects. Seven of the nine new PhD candidates were former MSc students at NTNU. The Centre organized a seminar in the spring of 2016 in order to attract new MSc students for 2017. One of CASA's goals is to train 20 PhDs over eight years. 13 candidates were employed in 2015 and 2016. The Centre's ambition is to attract Norwegian candidates and to improve the gender balance in the research field. Many Norwegian candidates have been recruited but so far only one female candidate has been employed at CASA. Further recruitment measures are needed, and will be initiated in the years to come. As part of this, a class of upper secondary school students visited CASA on 9 November. The students attended a presentation of the Centre followed by a tour in the laboratories and witnessed a crash box test in the pendulum impactor. CASA's communication officer Albert Collett was invited to give a presentation about CASA to upper secondary school advisors on 16 March.

MSc students
The following MSc students (22 male and 2 female) were associated with the Centre in 2016

STUDENT	TOPIC
O. I. Bengtson	Mechanical behaviour of sacrificial sandwich panels
S. Bergo	Micromechanical Modelling and Simulation of Ductile Fracture in Metallic Materials
B. Boger	Behaviour and modelling of TPU
K. A. Brekken and P. T. Ingier	Modelling of Window Glasses Exposed to Blast Loading
F. S. Dalen	Progressive collapse of buildings caused by explosion
M. Eek and K. K. Kaldager	Modeling of Work Hardening for Aluminum Alloy Structures
H. M. Granum and L. M. Løken	Experimental and Numerical Study on Perforated Steel Plates Subjected to Blast Loading
S. Guddal	Welding on Power Pylons in Aluminium
E. Hillestad and J. E. Pettersen	Experimental and Numerical Studies of Plain and Reinforced Concrete Plates Subjected to Blast Loading
S. Johansen and E. Waldeland	An experimental and numerical study of bolt and nut assemblies under tension loading
E. J. Lien and A. Skyrud	Impact Behaviour of Stiffened Aluminium Plates
A. Myräng	Oppførsel av plastmaterialer ved lave temperaturer
A. V. Nesje and P. A. Nilsen	Power Pylons in Aluminium
M. F. Paus	Quasi-static and dynamic behaviour of fillet welded connections
B. Sigurdsson	Foam Materials used for Energy Absorption and Damage Prevention during Blast Loading
S. Thomesen	Impact Behaviour of Steel at Low Temperatures
J. Øygarden	Plastmaterialer påkjent av skjærbelastning

PUBLICATIONS & ANNUAL ACCOUNTS

The following lists journal publications and conference contributions generated in 2016

Journal publications

1. V. Aune, E. Fagerholt, K.O. Hauge, M. Langseth, T. Børvik. Experimental study on the response of thin aluminium and steel plates subjected to airblast loading. International Journal of Impact Engineering 90 (2016) 106-121.
2. V. Aune, E. Fagerholt, M. Langseth, T. Børvik. A shock tube facility to generate blast loading on structures. International Journal of Protective Structures 7(3) (2016) 340-366.
3. T. Børvik, L.A. Marken, M. Langseth, O.S. Hopperstad, G. Rørvik. Influence of sigma-phase precipitation on the impact behaviour of duplex stainless steel pipe fittings. Ships and Offshore Structures 11 (2016) 25-37.
4. M. Costas, D. Morin, M. Langseth, L. Romera, J. Díaz. Axial crushing of aluminium extrusions filled with PET foam and GFRP. An experimental investigation. Thin-Walled Structures 99 (2016) 45-57.
5. L.E.B. Dæhli, T. Børvik, O.S. Hopperstad. Influence of loading path on ductile fracture of tensile specimens made from aluminium alloys. International Journal of Solids and Structures 88-89 (2016) 17-34.
6. L.E.B. Dæhli, J. Faleskog, T. Børvik, O.S. Hopperstad. Unit cell simulations and porous plasticity modelling for recrystallization textures in aluminium alloys. Procedia Structural Integrity 2 (2016) 2535-2542
7. E.L. Grimsmo, A. Aalberg, M. Langseth, A.H. Clausen. Failure modes of bolt and nut assemblies under tensile loading. Journal of Constructional Steel Research 126 (2016) 15-25.
8. E.L. Grimsmo, A.H. Clausen, A. Aalberg, M. Langseth. A numerical study of beam-to-column joints subjected to impact. Engineering Structures 120 (2016) 103-115.
9. G. Gruben, M. Langseth, E. Fagerholt, O.S. Hopperstad. Low-velocity impact on high-strength steel sheets: An experimental and numerical study. International Journal of Impact Engineering 88 (2016) 153-171.
10. M. Helbig, E. Van Der Giessen, A.H. Clausen, T. Seelig. Continuum-micromechanical modeling of distributed crazing in rubber-toughened polymers. European Journal of Mechanics – A/Solids 57 (2016) 108-120.
11. J.K. Holmen, J. Johnsen, O.S. Hopperstad, T. Børvik. Influence of fragmentation on the capacity of aluminum alloys subjected to ballistic impact. European Journal of Mechanics – A/Solids 55 (2016) 221-233.
12. J.K. Holmen, L.E.B. Dæhli, O.S. Hopperstad, T. Børvik. Prediction of ductile failure using a phenomenological model calibrated from micromechanical simulations. Procedia Structural Integrity 2 (2016) 2543–2549.
13. A. Ilseng, B.H. Skallerud, A.H. Clausen. Tension behaviour of HNBR and FKM elastomers for a wide range of temperatures. Polymer Testing 49 (2016) 128-136.
14. M. Khadyko, S. Dumoulin, O.S. Hopperstad. Texture gradients and strain localisation in extruded aluminium profile. International Journal of Solids and Structures 97 (2016) 239-255.
15. M. Khadyko, S. Dumoulin, G. Cailletaud, O.S. Hopperstad. Latent hardening and plastic anisotropy evolution in AA6060 aluminium alloy. International Journal of Plasticity 76 (2016) 51-74.
16. M. Kristoffersen, T. Børvik, M. Langseth, O.S. Hopperstad. Dynamic versus quasi-static loading of X65 steel pipes. European Physical Journal, 225(2) (2016) 325-334.
17. M. Kristoffersen, T. Børvik, O.S. Hopperstad. Using unit cell simulations to investigate fracture due to compression-tension loading. Engineering Fracture Mechanics 162 (2016) 269-289.
18. J.K. Sønstabø, D. Morin, M. Langseth. Macroscopic modelling of flow-drill screw connections in thin-walled aluminium structures. Thin-Walled Structures 105 (2016) 185–206.
19. V. Vilamosa, A.H. Clausen, T. Børvik, B. Holmedal, O.S. Hopperstad. A physically-based constitutive model applied to AA6082 aluminium alloy at large strains, high strain rates and elevated temperatures. Materials and Design 103 (2016) 391-405.
20. D. Vysochinskiy, T. Coudert, O.S. Hopperstad, O.G. Lademo, A. Reyes. Experimental detection of forming limit strains on samples with multiple local necks. Journal of Materials Processing Technology 227 (2016) 216-26.
21. I. Westermann, K.O. Pedersen, T. Børvik, O.S. Hopperstad. Work-hardening and ductility of artificially aged AA6060 aluminium alloy. Mechanics of Materials 97 (2016) 100–117.

Invited and guest lectures

Professor Magnus Langseth gave a presentation of SFI CASA at the Research Council of Norway's annual conference Vareproduksjonsdagene on 7 January, Sundvolden, Norway.

SFI CASA's communication officer Albert Collett presented CASA's media strategy at the Research Council of Norway's annual conference Vareproduksjonsdagene on 7 January, Sundvolden, Norway.

Professor Magnus Langseth held a presentation on implementation of research results at a seminar for the SFI centres organized by the Research Council of Norway on 28 April, Oslo, Norway.

Professor Tore Børvik gave an invited lecture on Structural design of protective structures – do we need new knowledge? at the Norwegian National Security Authority's annual Security conference on 16 March, Oslo, Norway.

Conference contributions

1. V. Aune, G. Valsamos, F. Casadei, M. Larcher, M. Langseth, T. Børvik. Inelastic response of thin aluminium plates exposed to blast loading. 1st International Conference on Impact Loading of Structures and Materials (ICILSM), Turin, Italy, 22–26 May 2016.
2. L.E.B. Dæhli, J. Faleskog, T. Børvik, O.S. Hopperstad. Unit cell simulations and porous plasticity modelling for generic fcc textures. 21st European Conference on Fracture (ECF21), Catania, Italy, 20–24 June 2016.
3. L.E.B. Dæhli, D. Morin, T. Børvik, O. S. Hopperstad: Influence of a high-exponent isotropic yield criterion on the macroscopic yielding and plastic instability of porous ductile solids 15th European Mechanics of Materials Conference (EMMC15), Brussels, Belgium, 7–9 September 2016.
4. M. Costas, J. Díaz, L. E. Romera, D. Morin, M. Langseth. Experimental characterization and numerical multi-objective optimization of the crashworthiness of aluminium extrusions filled with PET foam and GFRP. 1st International Conference on Impact Loading of Structures and Materials (ICILSM), Turin, Italy, 22–26 May 2016.
5. B.H. Frodal, K.O. Pedersen, T. Børvik, O.S. Hopperstad. Effect of Pre-Compression on Ductile Fracture of Aluminium Alloys. European Mechanics of Materials Conference 15 (EMMC15), Brussels, Belgium, 7–9 September 2016.
6. E. Grimsmo, A.H. Clausen, A. Aalberg, M. Langseth. Dynamic response of beam-to-column joints. 1st International Conference on Impact Loading of Structures and Materials (ICILSM), Turin, Italy, 22–26 May 2016.
7. J.K. Holmen, J.K. Solberg, O.S. Hopperstad, T. Børvik. Ballistic perforation of layered and surface-hardened steel plates. 1st International Conference on Impact Loading of Structures and Materials (ICILSM), Turin, Italy, 22–26 May 2016
8. J.K. Holmen, L.E.B. Dæhli, O.S. Hopperstad, T. Børvik. Prediction of ductile failure using a phenomenological model calibrated from micromechanical simulations. 21st European Conference on Fracture (ECF21), Catania, Italy, 20–24 June 2016.
9. M. Kristoffersen, K. Osnes, S.R. Haug, V. Aune, T. Børvik. Shock tube testing and numerical simulations of concrete slabs. 1st International Conference on Impact Loading of Structures and Materials, Turin, Italy, 22–26 May 2016.
10. C.O. Paulsen, E. Fagerholt, T. Børvik, I. Westermann. Deformation and damage mechanisms in a high strength dual-phase steel investigated by in situ scanning electron microscope tensile testing and digital image correlation. European Mechanics of Materials Conference 15 (EMMC15), Brussels, Belgium, 7–9 September 2016.
11. C.O. Paulsen, E. Fagerholt, T. Børvik, I. Westermann. Deformation and damaging mechanisms of a ferritic-pearlitic dual phase steel by in situ SEM tensile test. 17th International Conference on Experimental Mechanics (ICEM17), Rhodes, Greece, 3–7 July 2016.
12. C.O. Paulsen, E. Fagerholt, T. Børvik, I. Westermann. Use of digital image correlation on local deformations in pearlitic steel during in situ tensile testing in SEM. SCANDEM2016, Trondheim, Norway, 7–10 June 2016.
13. J.K. Sønstabø, D. Morin, M. Langseth. A cohesive element model for large-scale crash analyses in LS-DYNA. 14th LS-DYNA® International Conference, Dearborn, MI, USA, 12–14 June 2016.
14. J.K. Sønstabø, D. Morin, M. Langseth. Macroscopic Modelling of Flow-Drill Screw Connections. 13th International Aluminium Conference – INALCO 2016, Naples, Italy, 21–23 September 2016.
15. V. Vilamosa, T. Børvik, O.S. Hopperstad, A.H. Clausen. Local measurements of post-necking strains in a split-Hopkinson tension bar system incorporating heating. European Mechanics of Materials Conference 15 (EMMC15), Brussels, Belgium, 7–9 September 2016.

Annual accounts

SFI CASA FUNDING 2016 (ALL FIGURES IN 1000 NOK)

Item	Host NTNU	Research partner SINTEF	Public partners	Industrial partners	RCN grant	Total funding
Research programmes	7100	1100	2525	7516	7525	25766
Equipment			204	459		663
Administration	1000		1421	3675		6096
Total budget	8100	1100	4150	11650	7525	32525

SFI CASA COST 2016 (ALL FIGURES IN 1000 NOK)

Item	Host NTNU	Research partner SINTEF	Public partners	Industrial partners	Total cost
Research programmes	15616	6300	700	3150	25766
Equipment	663				663
Administration	6096				6096
Total budget	22375	6300	700	3150	32525

CASA

Annual Report 2016

Centre for Advanced Structural Analysis

Stories & Profiles

sfi Centre for Research-based Innovation

SINTEF

NTNU

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 new 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.

COVER

30 potential project and master's students turned up at SIMLab's presentation in May. Here some of them listen to CASA Director Magnus Langseth in the lab after seeing the kicking machine hit a shock absorber.

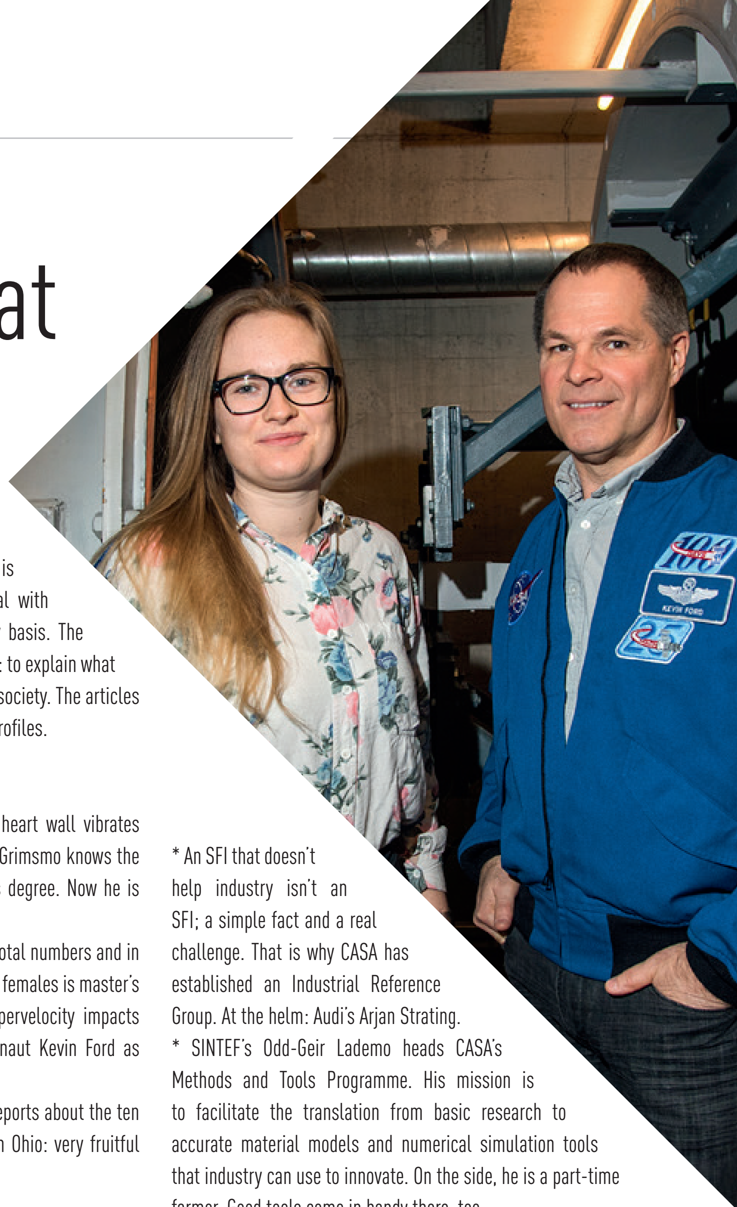
PHOTOS THIS SECTION

Cover: Albert H. Collett. Pp. 4-11: Lena Knutli.
Page 12: Ole Morten Melgård.
Page 15: Leif Arne Holme.
Page 16: Øyvind Hagen, Statoil.

GRAPHIC DESIGN

NTNU Grafisk senter

...and what is this?



This is the popularized part of the annual report. This is a glimpse of what CASA is all about for those of us who don't deal with heterogeneous microstructures on a daily basis. The aim is the same as in the rest of this report: to explain what goes on in CASA and why it is important to society. The articles here come in two categories: stories and profiles.

HEART WALLS AND STEEL JOINTS

* Every time a cardiac valve closes, the heart wall vibrates from the impact. PhD candidate Erik Løhre Grimsmo knows the phenomenon. He studied it in his master's degree. Now he is into steel. Much of the theory is the same.

* Interest in SIMLab is record high both in total numbers and in percentage of female applicants. One of the females is master's student Else Tjønn. She will simulate hypervelocity impacts between spacecraft and debris with astronaut Kevin Ford as supervisor.

* PhD candidate Johan Kolstø Sønstabø's reports about the ten weeks he spent at Honda R&D Americas in Ohio: very fruitful for both parties.

ALUMINIUM SALMON MUSTARD FOAM

* Professor Aase Reyes is into foams: "They weigh next to nothing and they absorb energy. The combination of the two characteristics makes them attractive to the automotive industry. They keep coming back for more research," she says. The salmon and mustard? You'll find out.

* An SFI that doesn't help industry isn't an SFI; a simple fact and a real challenge. That is why CASA has established an Industrial Reference Group. At the helm: Audi's Arjan Strating.

* SINTEF's Odd-Geir Lademo heads CASA's Methods and Tools Programme. His mission is to facilitate the translation from basic research to accurate material models and numerical simulation tools that industry can use to innovate. On the side, he is a part-time farmer. Good tools come in handy there, too.

* Finally, like last year, there is a story you shouldn't read. OK?

Contents

HEART WALLS and Steel Joints

Every time a cardiac valve closes, the heart wall vibrates from the impact. Erik Løhre Grimsmo knows about this. He studied the phenomenon in his master's degree. Now he's into steel. Much of the theory is the same.

More heart details: every time the aortic valve closes, a small wave is generated. The wave travels along the heart wall. The speed of the wave is governed by the stiffness of the heart. This, in turn, says something about the health condition of the heart. In his master's degree, Erik Løhre Grimsmo used numerical simulations to investigate how the wave propagation was affected by material properties such as the stiffness. The aim was to use the findings as a diagnostic tool.

ALL ABOUT MECHANICS

In his PhD thesis, he has switched material. The topic is how steel joints, nuts, bolts and welds behave under impact loading.

"Much of the background theory is the same as in the case of the heart. It's all about mechanics," he insists.

That might well be. Nevertheless, there is a slight difference between a cardiac valve inducing a wave in the heart wall and a steel container falling down onto the deck of an oil rig. This exact difference is one of the challenges of his PhD work. Full-scale tests at this level are demanding when it comes to performing them in a controlled manner, measuring the rapid deformation and extreme forces acting on the test specimens and then comparing static and dynamic responses. Not only that: the tests that are carried out have to be simulated afterwards.

UNDER STRONG INFLUENCE

A glance at Erik Løhre Grimsmo's family background can explain why choosing a PhD education was innate. His mother is a psychologist and an assistant professor at NTNU; his father a physician and professor at St. Olav's Hospital, both in Trondheim.

Then you have his brothers, both of them with PhDs from NTNU. One is a computer expert working for Google in Zurich; the other a quantum physics researcher at the Université de Sherbrooke in Canada.

HARD CHOICE

Still, while the background indicates a strong inclination towards an academic career, Erik Løhre Grimsmo wasn't so sure:

"Before finishing my master's degree, I got a job offer from Statoil in Oslo. Passing all the tests at Statoil was an elaborate process in itself. There were a whole series of them, ranging from IQ to English to group cooperation to presentations to multitasking. In the latter, we had to weigh speed against accuracy, handling the challenges of a virtual email inbox bursting with all kinds of different challenges.

When I finally passed and was offered the job, I was seriously tempted. My girlfriend studied medicine in Oslo and had two years to go. We had long discussions."

"And now?"

"I am very happy about my choice. I have a lot of freedom here at NTNU. I can continue educating myself and dig into the details.

The deal with my now wife is that when I have finished my PhD, we will most likely return to the Oslo region, where she is from."

NOT SO SPECIAL

PhD candidates are a special breed. Or are they? Erik Løhre Grimsmo begs to differ:

"I've heard many times that you need to have a special interest in your topic to become a good candidate. I tend to think that if you work intensely with something, you get interested. What you experience as you go along is that you become deeply absorbed in whatever it is you are doing. A little self-discipline is never amiss, but there is no need for extreme qualities. Independence is good, as is the ability to listen to others and receive advice."

FROM NERVOUS TO HAPPY

In his first years as a student, Erik Løhre Grimsmo felt uneasy about giving presentations:

"I was so nervous I trembled," he confesses. Then he took a course. He learned how to handle the stress, first in small groups, then gradually in larger ones. As a scientific assistant he initially had to give lectures to 60 or 70 students.

"Now I have audiences of 300 students or more and feel very comfortable about it. It's been a really positive leap. Even better, I now enjoy teaching, so I wouldn't mind if my future job involves some teaching."

Record Interest in SIMLab

Student interest in the SIMLab research group has never been higher.
This is promising news for the quality of SFI CASA master's students and PhD candidates.

The good signs were evident when SIMLab presented itself to potential project and master's students in May: 30 NTNU students in their fourth year attended the meeting. The impression was further strengthened when 17 of them put SIMLab as first choice for their project and master's work. Although they were not at the information meeting, another 17 students had the same priority, adding up to a total of 34 students. This is considerably better than the 2015 total of 25 and an all-time high.

BETTER GENDER BALANCE

In the application for a new SFI, SIMLab stressed its ambition to recruit more female students and staff. Several measures have been taken since SFI CASA opened officially on 1 July 2015. The project and master's applications in 2016 seem to reflect that the work is beginning to pay off: in 2015, only 5 of the 25 applicants were female. In 2016, 10 applicants were female. Even with the total number up to 34, the female percentage increased considerably.

PRESENTATIONS AND GUIDED TOUR

The presentation in May was led by Professor Arild Holm Clausen, who started by introducing the students to SIMLab and the content of the project and master's work. He also told the students that CASA partners BMW, Toyota and Audi want to engage a number of master's students in specific research tasks.

Professor Holm Clausen was followed by three PhD candidates. Vegard Aune presented his work on the behaviour and modelling of deformable plates subjected to blast loading, Jens Kristian Holmen talked about computer-aided design of lightweight protective structures and Erik Løhre Grimsmo about the behaviour of steel joints, nuts, bolts and welds under impact loading. Master's students Henrik Møgster Granum and Lars Marcus Løken followed suit.

After the presentations, the group was given a guided tour of SIMLab's lab facilities. This included a demonstration of what happens when the kicking machine hits a shock absorber.

MIXED GROUP

The students at the presentation specialized in both structural engineering in the Engineering and ICT programme and the Civil and Environmental Engineering programme and industrial mechanics in the Mechanical Engineering programme.

Pizza, refreshments and informal conversation between staff, PhD candidates and interested students rounded off the session.

CONTINUED INTEREST

Of the 34 students that applied in May, 30 eventually carried out their project work at SIMLab during the autumn. 23 of these continued with their master's theses in 2017. Although the number of female students has fallen to five, this means that 22 per cent of the participants are female: still a record.

One of the five is Else Tjønn, pictured on the opposite page with supervisor Kevin A. Ford. Her master's thesis deals with the challenges of debris in space.

ENTERING SPACE

Here she explains:

"One of the great challenges when it comes to space travel is the large amount of debris orbiting the earth at very high velocities. This debris is mostly man made and stems from old satellites, launch vehicles etc. It may impact against a spacecraft at up to 16 km/s in the low earth orbit, possibly leading to the loss of vehicle and crew.

All spacecraft today are covered to some degree with shields for protection from this debris. One of the goals in my thesis is to simulate these hypervelocity impacts using new methods and see if there is a good resemblance to the physical experiments that are already performed. I will also be looking at various designs to see if there is a possibility of improvement."

ASTRONAUT SUPERVISOR

As mentioned, one of Else Tjønn's supervisors is Kevin A. Ford. The accomplishments of this newly recruited NTNU researcher include a long military career, a PhD in astronautical engineering and a total of 157 days in space.

In the picture, the two have a rendezvous in SIMLab's gas gun, where Else Tjønn is going to perform some of her tests. The image illustrates well one of the main conclusions from SFI CASA's Scientific Advisory Board after their meeting last October: the centre's unique combination of experimental facilities in blast, ballistics and fragmentation gives an opportunity to invent new material systems for protection.

MY STAY WITH Honda R&D Americas

PhD candidate Johan Kolstø Sønstabø spent ten weeks at Honda R&D Americas as part of his work on flow-drill screw connections to join aluminium sheets. Here is his report from the stay:

"I became involved with Honda as a master's student, when Professor Magnus Langseth wanted me to study flow-drill screw connections between aluminium plates for Honda R&D Americas. They had contacted SIMLab and wanted to invest in a long-term strategic partnership. Therefore, this became the topic for my master's and PhD theses. This was in 2012.

MUTUAL BENEFIT

I had been working on the project for two and a half years when we thought it was time for me to go and work with Honda for a while. We anticipated that this would be beneficial both for me and for the partnership between Honda and SIMLab. The people at Honda were excited and we decided on a ten-week stay.

On 11 April I found myself in the huge parking lot in front of the R&D building in Columbus, Ohio. Coming from a tiny island in Norway where there are ten cars per hour on heavy-traffic days, the size of things at Honda amazed me. I was working in a shared office space with two thousand others. The office was the size of three football fields, very different from the SIMLab environment. Working in such a large company was very interesting. I learned a lot about being a small part in a big machine and about the dynamics of large companies. A couple of weeks after I started, we worked out a draft work plan for my stay, based on previous discussions. Honda had a list of suggestions about what I could do there. Professor Langseth and Associate Professor David Morin gave their input to the plan in a video meeting. I believe that this was a key point for the success of my stay. Now the partners and I had a mutual agreement about the expectations and I could spend the limited time efficiently.

FULL-VEHICLE CRASH SIMULATIONS

While at Honda, I had the opportunity to work with full-vehicle crash simulations. The size and complexity of these simulations are astonishing, with 15 million elements and thousands of different parts. In my PhD research I have been working on how to model FDS connections in large-scale finite element simulations. However, before I went to Honda I had only worked on rather simple simulations, mostly with a single connector. To understand the physics of what is going on in a connection, we performed experiments with simple test specimens under controlled loadings. Furthermore, to evaluate the accuracy of different macroscopic modelling techniques for FDS connections, we simulated the tests and compared the results with the test results. Working with the full-vehicle simulations at Honda gave me valuable experience regarding FDS modelling as well as experience with different aspects of large finite element simulations in general. For Honda it was valuable to learn how to use the macroscopic model that was currently most promising for FDS connections.

INCREASED KNOWLEDGE TRANSFER

An important motivation for SIMLab to send me to Honda was to increase the knowledge transfer between the two partners. One of SIMLab's strengths is the modelling of aluminium and Honda is using aluminium in several of their cars. This was therefore a good opportunity for Honda to apply and understand the SIMLab Toolbox and the SIMLab Metal Model. I held workshops for people in my work group involved in the modelling of anisotropic aluminium where I lectured on the Toolbox and they got hands-on experience using it for the calibration of the Metal Model. I believe this experience was very interesting for Honda. Eric DeHoff, a senior researcher at the core methods group, said that he had listened to presentations from SIMLab about the Toolbox several times but had not really understood it until now. I believe this is a good example of how we can efficiently transfer knowledge between SIMLab and our industrial partners.

DIFFERENT PHILOSOPHIES

Knowledge transfer goes both ways. Working on aluminium modelling with Honda gave me the opportunity to learn about their philosophy when it comes to material modelling and the models they are using. One aspect was that SIMLab and Honda have some significantly different philosophies. For large-scale simulations, the philosophy at SIMLab is to use simple parameterized phenomenological material models which conform to well-established physical principles (like positive plastic dissipation). The complexity of the models and the number of calibration tests needed, depend on what physical behaviour you want to capture in the simulations (for instance anisotropic behaviour). At Honda, the result in the end (comparison between component simulation and the experiment) is most important, not whether the models comply with physical principles. If a model violates a few thermodynamic principles but is easy to calibrate and gives satisfactory predictions of the anisotropic behaviour, an engineer will use it anyhow. I believe this is a common difference between academia and industry. Understanding the different ways of thinking is important to "bridge the gap" between SIMLab and its industrial partners and between academics and industry in general.

ROOM FOR IMPROVEMENT

While my stay at Honda was a success, I hope the experience from my visit can improve other PhD candidates' future stays with our industrial partners. However, one thing comes to mind. During the short time I was there, I did not participate much in the work they do at Honda. I spent my time working on the items in my work plan that we set up during the first weeks. I wish I could have been more involved in some of the current projects other people in my group were working on. In retrospect I realize that this is a point that should have been included with the rest of the items in the work plan in the first place.

Long story short: I have learned a tonne, gained experience for myself and SIMLab, had fun and made new friends."


DNB
TEEKAY

ALUMINIUM Salmon Mustard Foam

Confused? Good. In real life, mustard and honey go on top of the salmon loin when SFI CASA Professor Aase Reyes prepares dinner. The aluminium foam stays at work.

"I wouldn't say I'm a master chef, but I do enjoy cooking," Reyes confesses. The salmon recipe just cited was served for dinner the day before this interview. It's a family favourite, also with the six- and nine-year-olds.

RE-ENTERING FOAMS

"What is it with foams?"

"They weigh next to nothing and they absorb energy. The combination of the two characteristics makes them attractive to the automotive industry. They keep coming back for more research."

Which explains why Reyes is back to foams as part of a many-faceted professional journey.

Her master's thesis was on earthquakes, with a plan to become a bridge engineer. That never happened. Her fascination for research had been ignited. Like several of her peers, she had a chat with CASA director Magnus Langseth on the way. She knew he was looking for new PhD candidates. She applied for a faculty scholarship in 1998 and was awarded one.

MATERIAL TORTURE

So she met foams, first in aluminium, and took her PhD on the topic. Titles like "Constitutive modelling of aluminium foam including fracture and statistical variation of density" and "Aluminium foam-filled extrusions subjected to oblique loading: experimental and numerical study" illustrate the work she performed more than a decade ago.

Even to a non-expert, one message emerges from these titles: like all other SFI CASA professionals, Aase Reyes has extensive experience in the disciplines of torturing materials and structures. And she enjoys it.

"Performing tests is great fun. What I enjoy even more is the task that follows, analysing the test data and digging further into the matter," she confesses.

FORMABILITY

After defending her PhD came a period without foams. One of the reasons was that SIMLab partner Hydro sold their foam-producing unit. The formability of aluminium alloys became a focus area. As supervisor for PhD Candidate Dmitry Vysochinskiy, she helped investigate the possibilities for establishing reliable methods and tools to get the relevant data out of the tests performed.

Although she also reviews articles on impact, fracture and formability, a large percentage of the articles she receives for review still deal with foam. Low weight and high capacity for absorbing energy continues to be an attractive combination. Even so, its use is limited. For several reasons. One is the relatively costly production of aluminium foam; another is the need for more research.

A KNITTER AND A READER

All female professors at SFI CASA run, but Aase Reyes is eager to point out that she doesn't take it as far as her colleague Randi Holmestad, who risks being reported sick if she isn't heard running in the corridors of her workplace.

Reyes prefers a beach, if she can. She first discovered the joy of beach running during a nine month research sabbatical in Florida. Since then she has tried Madagascar and Cuba. Her next beach could be in the Philippines, where she has relatives.

She also knits, but only for family members. And she reads. Amy Tan is a favourite, Isabel Allende another. Although both authors live in California, their respective roots in China and Chile are heavily reflected in their works. Aase Reyes likes that. She is drawn to new places and enjoys visiting them, even though it may provoke mixed feelings.

"Like Madagascar: definitely exciting, with impressive natural scenery and fascinating wildlife, but also with a stark contrast to our living conditions."

BACK TO FOAM

At present, Professor Reyes is back to foam. Polymer this time. The project of her latest PhD candidate, Daniel Morton, is to be able to model it better and thus increase the potential for innovative use in the automotive industry.

The starting point is to get an overview of the research that has already been done. From there, the challenge is to find the most interesting materials for research, putting them to the test, analysing the results, modelling the characteristics and validating them.

In addition to supervising PhD candidates, reviewing articles and all the rest, Reyes takes pleasure in teaching. That is part of being a dedicated professional, it seems.

NOT FORGETTING THE GARLIC

One more thing. Or two: garlic and lemon. Both should be added to the mustard and honey paste on the salmon. Bon appétit!

An SFI that doesn't help industry isn't an SFI; a simple fact and a real challenge. That's why CASA has established an Industrial Reference Group. At the helm: Audi's Arjan Strating.

INDUSTRIAL Reference Group in the Mould

SIMLab, the main research group behind SFI CASA, has nothing to be ashamed of when it comes to delivery. When 64 Norwegian technological research groups were evaluated in 2015, two were rated world-leading. SIMLab was one of them. Research quality, industrial impact and organization were the main criteria. However, as is often the case, the better you excel at something, the better you understand the potential for improvement. So CASA decided to form the IRG.

A CERTAIN LOGIC

Although there is no immediate connection, there is a certain logic to an Audi guy heading the IRG: Strating's colleague Thomas Hambrecht was closely involved in the establishment of the SIMLab Tool Box. In many ways the IRG and the Tool Box serve the same purpose – moving scientific findings from journals to industrial applications.

The mandate asks the IRG to propose deliverables from the Methods and Tools Programme, where the Tool Box is a central instrument, to evaluate and schedule the implementation of the obtained results, and give guidelines on how to carry out implementation.

TRIGGERED BY SIMLAB

Arjan Strating says it like this:

"IRG will have an advisory function with focus on industrial application. We all need to get something out of SFI CASA. In the case of the industrial partners, we need knowledge and tools that can improve product development.

"In this respect, SFI SIMLab served as a trigger and generated a considerable appetite. In 2007, it wasn't at all clear where it would end. When we got the tools in place, we reached industrial relevance.

"The Tool Box represents a jump-start for CASA. Without the tools, we would have risked a gap of three or four years before we reached industrial relevance again. All of us are much more aware of this need now than when we started SFI SIMLab. The challenge is to keep the momentum."

PIONEERS

The concept of establishing an Industrial Reference Group is new. Arjan Strating likes the challenge:

"There is no blueprint that we can take from somewhere, so one of the first things we have to do, is to fill the shell with life together with the IRG representatives," he says.

The partners have common responsibility for moulding the future results. The aim is to ensure that applicable knowledge migrates from CASA to enhanced product development in the partners' home organizations. Simply tapping the Tool Box is not good enough.

"It would be a great pity if the findings of SFI CASA end up in a drawer. We all know that this is a common phenomenon; often universities aren't able to provide the links that bring research to the market. To avoid this, our ambition will be a high level of participation where the partners articulate themselves in open discussions," Strating adds.

SURVEY

To get the process going, all partners have been sent two surveys with a series of questions. The answers revealed some of the challenges facing the IRG in their effort to work out an efficient implementation plan. A technical seminar in March and an IRG meeting in November discussed how the implementation must be linked to a strategy where the models and technology developed are validated on the basis of a generic experimental hierarchy. This means that tests must be representative for several business sectors. Other challenges are to define what is within the CASA domain and what is not, and how personnel can be used to support implementation.

SCEPTICISM TURNED AROUND

Strating confesses that he was a bit sceptical about the idea of the surveys.

"Now I am very happy about it. We received some very clear and converging answers. The partners know what they want: a Tool Box that can be easily interpreted and available for daily use. At the same time we realize that we have to raise awareness that everyone has a responsibility to contribute," he says.

The IRG meeting in November revealed that there was strong common interest in integrating the knowledge and tools from CASA into everyday engineering applications across all business sectors. Most of the partners want to see the CASA tools coded into commercial finite element solvers as soon as possible. The requests for application guidelines and training in using the tools are steadily increasing.

IMPROVED FUTURE STANDARDS

"It is very encouraging to observe that more and more partners have started internal activities around the Tool Box. Intensive benchmark studies against established commercial models and the exchange of employees between industry and NTNU for knowledge transfer are good examples. This is a clear indication of the potential of the tools and shows that industry considers that CASA's tools could contribute to improved future standards in numerical simulations. This emphasizes the need for a continuous implementation process in an industrial context even more.

"The plan to establish a uniform validation hierarchy has also reached the next step. All business sectors involved share a relevant common basis regarding materials, joints and loading situations. Of course there are some blind spots in the landscape, but it is a good and efficient starting point to design tests and procedures from. So, it may not surprise you that I am looking forward to next IRG meeting in May 2017 in Ingolstadt with excitement," Strating sums up.

HEAD of Tools

On top of a hill in Verdal lies a farmhouse with the most spectacular view of the valley below. It is the home of Odd-Geir Lademo, head of CASA's Methods and Tools Programme.

"I hate living in cities," he says. His main workplace is in Trondheim, a 90-minute drive to the south. Still he prefers to return to the farmhouse every night. Luckily, he can work from home part of the time.

Lademo grew up in similar surroundings not far away. His present dwelling comes from his wife's family: she took over the farm according to Norwegian law, where the oldest child inherits. Today, wife and husband have separate responsibilities: she milks the cows; he does the harvesting.

CLOSE TO PRACTICALITIES

Ignoring the practical aspects of life is impossible on a farm. Animals need care, seeds must be sown; something always needs mending or improving. Odd-Geir Lademo is all the happier. The swap from basic research to the challenges of putting knowledge to use suits him just fine.

In his own words:

"Our mission in SFI CASA is to make methods and tools that are useful for industry, starting out from hands-on experimental procedures to test materials thoroughly. We also make tools to organize the experimental results and process the data. These data are used to develop accurate material models and numerical simulation tools that industry can use to innovate."

MANY SHAPES AND FORMS

The Methods and Tools Programme comes in many shapes and forms. One is taking thousands of images of all kinds of deformations and strains from different angles in a digital image correlation system. The pictures are processed numerically and the results translated. This provides new fundamental insight into how materials deform and fail, as well as verifying the data tools used by industry.

The research covers many material classes and variants: aluminium alloys, steel, polymers, glass, foams, and possibly a touch of concrete. Each material class or material variant demands separate attention in terms of test procedures, model features and test results.

Modern, advanced characterization techniques also open the path for a deep dive into the materials. Separate tools will be developed to provide information in scale models that industry can exploit for applications such as crash analyses.

Tools to store, process and visualize the experimental data are obviously important, and are well planned.

Everything is gathered in the SIMLab Tool Box with direct access for all the partners. From there on, the innovation process at each partner takes over.

MIND THE GAP

Odd-Geir Lademo is just as much affected by CASA's challenges as the rest of the team. When the Scientific Advisory Board says "Mind the Gap", he takes their point.

"The distance between metres and nanometres is enormous. We can observe the alloy elements in aluminium at nanoscale, but we do not know the implications with respect to models," he confesses.

All CASA work starts with models formulated at a higher level. However, it is not self-evident that the researchers actually manage to reduce the scale and increase it again in a reasonable manner.

The Scientific Advisory Board pinpointed this issue in their report from last October:

"We are concerned that atomistic understanding does not correlate with partner needs."

This is a challenge, but fortunately it is one that CASA has every intention to face.

OPTIMIST

As it is, Odd-Geir Lademo loves challenges.

"I am also an incurable optimist. Some say too much so."

"Most of us have a positive quality that is also our weakest point. What is yours?"

"I say yes too often. In addition to heading the Methods and Tools Programme in CASA and holding a position as Adjunct Professor at NTNU, I am a research manager at SINTEF Materials and Chemistry. I also head the Parents' Council Working Committee at my children's school. I don't always have a good conscience leaving the bulk of the obligations at the farm to my wife. Luckily, SINTEF allows me to prioritize the farm in the most critical periods of the spring and harvesting. Even though the farming is hard work, I like to think of it as mental relaxation and a good alternative to a mountain cabin."

AN ANGLER AND A CARPENTER

Our man is closest to paradise when he can bring a tent and a fishing rod and spend several days fishing in mountain lakes.

He also financed much of his studies fishing. From when the ice broke up until it covered the Leksdalsvatnet lake again in the autumn he would get up early with his father and see to the nets. The record catch was 309 trout in one night. Shops in the neighbouring villages were good customers.

At high school, he first aimed at becoming a carpenter. Through this practical experience and education, he gradually became more interested in school work and theory. He completed his master's degree in Structural Engineering in 1992, having Professor Magnus Langseth as his supervisor for his diploma on blast loading.

He completed his PhD on materials modelling of aluminium alloys in 1999, having Odd Sture Hopperstad and Magnus Langseth as a strong supervisory duo. He then started working in SINTEF, still nurturing the strong link to NTNU, and the subject area of his PhD.

He is still there, but not all of him. Rather, he feels privileged to have two sets of tools: one at CASA and one on the farm.


Cocraft


SLEIPNER A
BLOKK 15/9
OPERATOR
STATOIL

Don't READ this

Did you read the «Don't Read This» article in last year's annual report?
Then you know that it wasn't about CASA. Nor is this year's version. So stay away, OK?

Not OK? Still reading? Well, some people just cannot be helped. Here, at your own risk, are a few words about the world outside CASA. You could say it is about the neighbours.

As you already know, CASA is an SFI; one of several funding schemes administered by the Research Council of Norway. Two of the others are Innovation building projects for industry (IPN) and Competence building projects for industry (KPN). Both of these have a more limited scope than an SFI. The similarity lies in the desire to help industry through research.

MOUNTAIN HIGH...

Did you know that it takes 12 helicopter trips to get a single power pylon to its destination? Since Norway is full of mountains, this means a lot of expensive transport. In comes IPN AluMast. The ambition is to make pylons of aluminium instead of steel. This could potentially reduce the need from 12 to 5 helicopter trips per pylon.

Researcher Marius Andersen works with the behaviour and modelling of aluminium columns in AluMast. After defending his PhD at SFI SIMLab he has turned his attention to the structural response of thin-walled aluminium tubes subjected to axial loading. The aim: to avoid buckling and collapse. In his work, Andersen will take advantage of the numerical simulation methods and experimental techniques available at SIMLab.

Understandably, CASA partner and aluminium producer Hydro is a partner in AluMast. So are SINTEF and many more.

...FJORD WIDE...

Did you know that the Norwegian Parliament wants to build a ferry-free highway – the new E39 – from Kristiansand to Trondheim? This involves crossing eight fjords, including the Sogne Fjord where it is 1.3 kilometres deep and 3.7 kilometres wide. A submerged floating tunnel is one of the solutions being considered. No such tunnel exists today.

When researcher Martin Kristoffersen defended his PhD at SFI SIMLab, the topic was oil pipelines subjected to impact. Since then he has changed material and dimensions: at present, he is investigating what would happen in an explosion inside a tunnel made of concrete. Thanks to SIMLab's shock tube, Kristoffersen is able to perform small-scale testing. The results are paired with numerical modelling to understand the behaviour of the concrete.

CASA partner the Norwegian Public Roads Administration has signed an agreement with NTNU including 20 PhDs dealing with the new E39 alone.

...AND THE DEEP BLUE SEA

Yes, you do know that polymers change behaviour at freezing temperatures. What you probably don't know very much about, is the details. This is PhD candidate Joakim Johnsen's domain. He works on the project Arctic Materials II, which is a consortium led by SINTEF. A number of other CASA partners participate as well: DNV GL, Statoil, Hydro and Sapa.

The main goal of Johnsen's PhD project is to develop a method to obtain local deformation data from experiments of polymers. He looks at the behaviour of two types of polymers at temperatures ranging from +25 to -30 degrees Celsius. He is also working on recording the self-heating in the material using an infrared camera.

Johnsen seeks to develop a material model that captures the change in material behaviour due to variations in temperature and strain. This is obviously crucial knowledge for the oil and gas industry and other operators in the Arctic.

CONDUCTIVITY VS. STRENGTH

SINTEF is also involved in several KPNs with links to CASA. Two of them are AMPERE and FICAL.

In AMPERE, the hunt is for the optimal combination of mechanical properties and electrical conductivity in aluminium alloys at elevated temperatures. Such properties are sought after in the engine room of cars, in heat exchangers and many other places. Potentially, aluminium could replace costly copper in subsea electric cables. CASA Professor Knut Marthinsen is project leader and other partners include Hydro and Sapa. SINTEF researchers Stéphane Dumoulin and Térence Coudert are also central in the project.

FICAL looks into aluminium grain borders with special attention on corrosion. There is a substantial potential for increased use of aluminium in the automotive industry and elsewhere. Improved mechanical and corrosion properties would further increase the potential.

FICAL attacks these challenges at the nanoscale and seeks to develop modelling tools for optimizing alloy design and performance. CASA Professor Randi Holmestad and SINTEF researchers Calin Marioara, Jesper Friis and Inga Ringdalen are all involved in the project.

TOPPFORSK

Then there is prestigious Toppforsk project FractAl which was the subject of last year's "Don't Read This" article. CASA Professors Odd Sture Hopperstad and Tore Børvik have teamed up with Hydro's Ole Runar Myhr and Professors Ahmed Benallal from the French university LMT-Cachan and Jonas Faleskog from the Royal Institute of Technology in Sweden.

The aim is to enable the design of both the material and structure of aluminium alloys in an optimal combination without having to use time-consuming and expensive mechanical tests.

And that's only a selection of the neighbours. Perhaps in the near future you will learn why results of CASA research are relevant to tap geothermal energy from the Earth's crust.