sfi Centre for Research-based Innovation
The Research Council of Norway

manufacturing

NEWSLETTER

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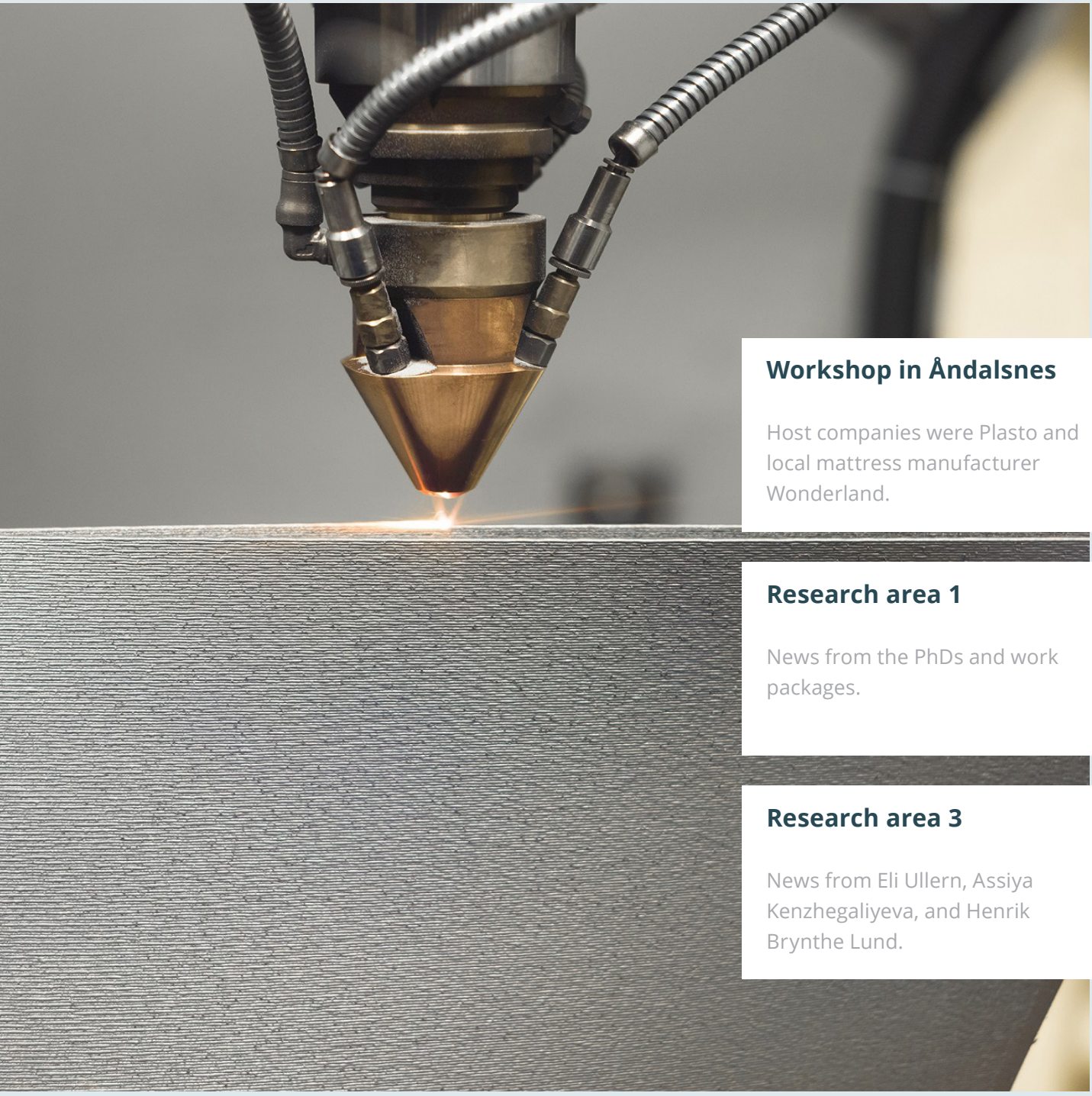

Workshop in Åndalsnes

Host companies were Plasto and local mattress manufacturer Wonderland.

Research area 1

News from the PhDs and work packages.

Research area 3

News from Eli Ullern, Assiya Kenzhegaliyeva, and Henrik Brynthe Lund.

Welcome

A message from the Centre Manager

This spring has been an active period for SFI Manufacturing.

In April, representatives from the board and center management was invited to a meeting with the Minister of Trade and Industry with focus of the need for increased support to industry-oriented R&D.

In May, the consortium developed to drafts for Green Platform applications to the Research council, and in the ongoing process these to drafts will most likely be merged into one application for the deadline September 14th. The working title for this application is GreenMan.

In June Linn Danielsen Evjemo defended her PhD thesis entitled "Additive manufacturing of thin-walled structures by robot manipulator: An experimental approach focusing on arc welding".

We congratulate Linn with finalisation of a nice research work.

In parallel with this defence, an industrial work-shop took place at Åndalsnes with more than 50 participants.

The focus area of the work-shop was Circular Manufacturing and Business Models, and Sustainable, Recyclable Materials and Products.

Thank you all for the contribution making all these activities possible!

Sverre G. Dahl.

In this issue

Industrial Workshop in Åndalsnes

Monday 20 to Tuesday 21 of June, it was a pleasure to welcome the SFI Manufacturing consortium to another industrial workshop, this time in Åndalsnes in the industrial community of Rauma. Host companies were partner Plasto plus local mattress manufacturer Wonderland.

These two companies are involved in research projects together (and by the way share managing director, our own chairman Lars Stenerud). 56 participants found their way to Åndalsnes where logistical challenges were posed not by strikes restricting air traffic, but by heavy train delays caused by a forest fire near Dombås (!)

The Research Council was present, as well as SIVA and local development organisation Nordveggen.
Monday evening started off with a brief introduction to 'Green Platform' and a general view on the future for industrial applied research in Norway. The Research Council (Norun Jetlund and Jan Rasmus Sulebak) provided some input in the light of the recent budget discussions and Gaute Knutstad contributed information on new offerings and calls from SIVA. A round of 'coffee-table' discussions followed, highlighting 3 sectors or areas targeted for a Green Platform application to be filed this September: Green and circular finished goods (B2C); green and circular products for green mobility; and green and circular products for sustainable aquaculture.

A spectacular ride with the Romsdalen Gondola took us up to Eggen restaurant at Nesaksla. Here we enjoyed a very nice dinner with local delicacies and a fabulous view of Åndalsnes including the sites to be visited the next day. Many of the participants chose to walk down the path including carefully crafted sections of stone staircases as well as the Rampestreken viewpoint.

Tuesday morning we got academic presentations from research areas 1 and 3.

RA3 on 'circular manufacturing and business models' providing presentations by Sigurd and Eli, Assiya, Henrik and Guiseppe covering the circular innovation journey of host company Plasto, environmental upgrading from different perspectives, and a circular assessment method for both plastic and aluminium value chains.

RA1 on 'sustainable, recyclable materials and products' provided a thorough overview of relevant topics form WP 1-3 on multimaterial products containing polymer based materials (Ben), lifetime prediction and structural degradation of polymer and polymer composite components (Chaman), and high-throughput materials discovery (Even).

Then Solveig Brøste Sletta from Nordveggen gave us a short introduction to the vibrant community of Rauma, home to not only an impressive amount of industrial companies, but also leading service, logistics and tourism companies.

Runar Stenerud gave us a presentation of Plasto focusing how this relatively small company has been able to run multiple R&D projects in close co-operation with research institutes and universities, funded by the research council.

The long-term focus in Plastos efforts to become more sustainable and more circular in their operations was truly inspiring.

Lars Stenerud followed to give us an introduction to Wonderland, a medium-sized company producing high-quality beds and mattresses with mostly a local supply chain.

This company's work to reduce the environmental footprint of a typical continental bed by 50% was highlighted. This IPN project 'WondRest' has Plasto and other suppliers, as well as furniture retail chain Møbelringen and SINTEF and NTNU as partners.

After lunch at the workshop hotel we ventured off to no less than three site visits: The Plasto highly automated factory including injection moulding of large aquaculture components based on recycled raw material.

The Wonderland mattress factory including a state-of-the-art automated mattress line producing a mattress in less than a minute.

The Wonderland showroom where we could lay down, maybe enjoy a short nap … and heard more from Lars and Lena about the WondRest project and the efforts to make a more sustainable bed.

A brief wrap-up session back at the hotel concluded the workshop.

We would again like to thank Plasto (and Wonderland) for opening up and sharing their thoughts and challenges towards a more circular and sustainable manufacturing future.

And to all the participants sharing their views and contributing to a successful workshop.

Håkon Raabe.

Research Area 1

Additive manufacturing: Rapid growth in the industrialization of AM

The industrialization of additive manufacturing (AM) technology continues to make great progress, with a rapidly increasing number of companies, using AM, as an integrated part in their industrial production.

In their 2019 survey, professional services network Ernest & Young Global Limited (EY), reported that the share of companies with any experience with AM had risen to 65% from 24 % in 2016, and the share of companies which apply AM in production had grown from 5% in 2016 to 18% in 2019 (1).

This number could mean that AM for final parts production has grown out of the group of „early adopters“ and is gaining momentum among the „early majority“ of manufacturing industries. In addition to this, 15% of the surveyed companies used AM to produce tools, and 14% used AM to make spare parts.

As the technological maturity of AM has been demonstrated many times in specific industries, a key reason why the adoption hasn‘t been faster is that individual firms still struggle with the adoption and implementation of AM at an industrial scale.

Companies often underestimate the extent to which the adoption of AM is first and foremost a learning process that will involve the entire value chain and require that specific AM expertise needs to be acquired (2).

There are several examples indicating that this tendency is not limited to industry but is also very much a constraining factor that hampers the development and application of AM competency in academia and at research institutes. Among the industries surveyed by EY in 2019, aerospace leads the way with over 78% of the respondents claiming to have experience with AM.

This is further demonstrated in a complementary EY report from 2020 (3), where the companies from the aerospace industry expected that the use of AM for end use part production would grow from 18% in 2019 to 59% in 2022.

The numbers for the chemical industry indicated an expected growth from 22% in 2019 to 53% in 2022, and for the automotive industry from 17% in 2019 to 44% in 2022.

The reason why automotive is lagging can be explained as a question of scale.

The number of parts manufactured in a series production in the aerospace industry is most often rather small compared to the typical numbers of parts manufactured in a series production for the automotive industry.

The high number of products needed for automotive series production brings critical constraints in the productivity and speed of handling of the parts during the break-out and unloading of the finished parts after each build cycle, -and throughout the postprocessing operations.

This challenge has been addressed through increasing the level of automation in the AM enabled process chain. This trend has been demonstrated by the presentation of a rapidly growing number of systems for automation in the AM process chain at the annual Formnext fair in Frankfurt during recent years, and the impact of this development is also reaching into the production of leading automotive manufacturing companies.

BMW have reported that their initiative for industrialization and digitalization of AM based production of automotive components in serial production has been successful (4).

The solution is described as „a digitally connected, fully automated additive manufacturing line, specifically for series production of automotive components“, which has the capacity for a cost-effective annual production of 50000 components in serial production, -and in addition to this, 10000 custom or new components.

This solution means that certain tools are no longer required for the manufacturing of these components, which reduces design constraints, and thus enabling new product solutions, and a much-increased manufacturing flexibility.

Since they started to investigate the possibilities of AM in the energy sector in 2016, Equinor has studied potential applications where AM could provide a competitive alternative production route.

Over time, the number of identified cases where AM can offer a clear business case have grown to more than a hundred different products.

Since the keeping and maintaining of a necessary supply of spare parts, represents a significant cost for Equinor, AM offers an attractive possibility to reduce large sections of the physical inventory, and replace it in the form of a digital inventory to be combined with AM enabled, on-demand, manufacturing.

The outcome of Equinor‘s investigations has been carried forward by the establishment of a „Centre of AM Excellence“.

Among the cases investigated is replacement of a set of obsolete locking screws for switch cabinets used on offshore installations.

Spare parts for the locking system are no longer available, and the only solution offered by the cabinet supplier was to replace the entire cabinets as the locking screws failed.

However, changing a cabinet would require rewiring and installation of a parallel system to be operated while the original cabinet is changed.

This was not very attractive since it would be a labor intensive and very costly solution. See figure 1.

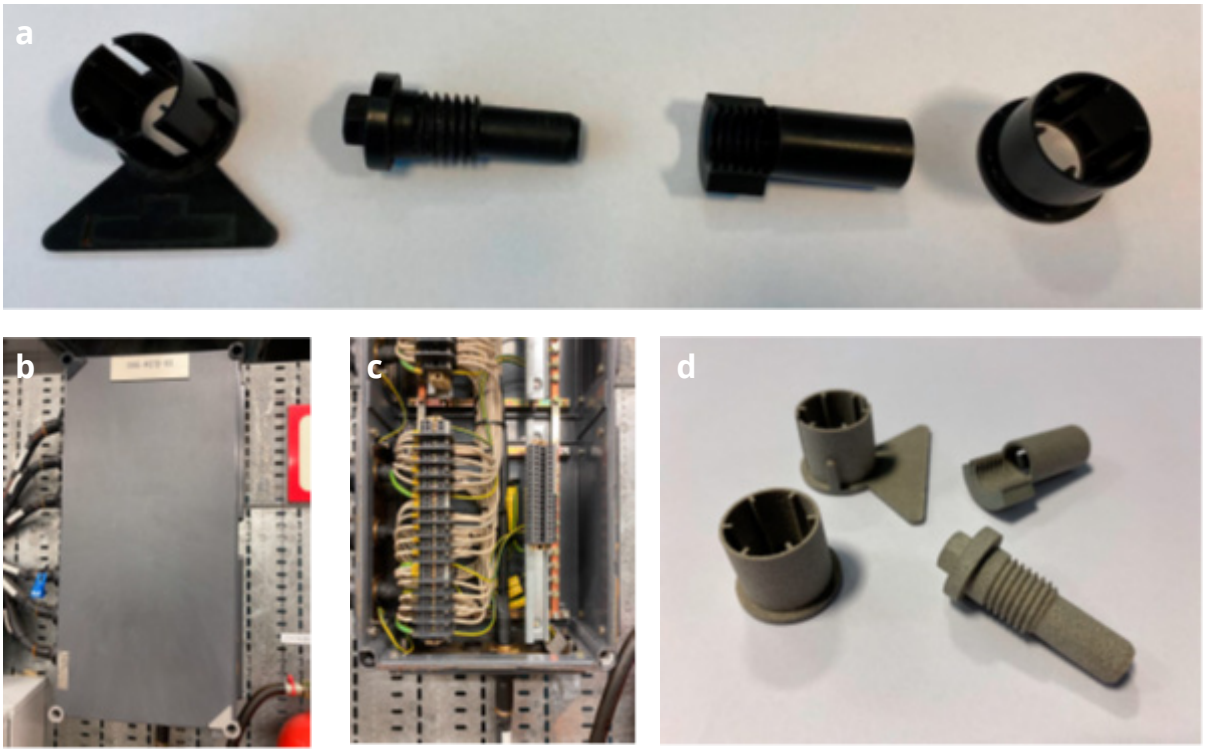

Figure 1: Spare parts for a switch cabinet: the original locking screws (a), positions in the cabinet (b & c), and the spare parts, manufactured by PBF-LB/PA12 (d). (Images provided by courtesy of Equinor and Karsten Moholt)

As an alternative solution, Equinor collaborated with electromechanical supplier Karsten Moholt, to find a different source of spare parts for the locking screws.

It was found that reverse engineered polyamide PA12 screws built by PBF-LB fulfilled the requirements for installations and Ex-markings .

A conservative estimate concluded that this solution would save Equinor over 100 million NOK, -annually.

Besides substantial economical savings, the AM enabled production of spare parts can also bring a significant decrease in environmental impact.

In a previous case, from 2018, the fan for a motor unit at Equinor's plant at Tjeldbergodden had broken down, and there where no spare parts available.

The supplier recommended that the entire motor unit should be replaced, which would be costly, and certainly would have a significant environmental impact.

As an alternative solution, Equinor turned to upstart company Fieldmade, who specializes in on-site and on-demand spare parts production, thus were able to successfully recreate the digital model for the spare part by reverse engineering, and built a replacement for the broken fan by AM.

See figure 2.

Figure 2: Fan for a motor and replacement part, made in the field by Fieldmade for Equinor during Trident Juncture 18. Since the original fan had gone out of production, reverse engineering and reproduction of this part was the only alternative to replacing the entire motor unit. Courtesy of Fieldmade and Equinor.

A calculation of the environmental impact has concluded that changing the entire motor unit would have had an impact of 4600 Kgs of CO2, while the impact of producing the spare part by AM was only 3.8 Kgs CO2. The difference in cost was of the same magnitude.

Supported by an industry consortium headed by Equinor, Fieldmade have developed a solution for a „Digital Inventory“ which enables distribution of product designs for on-demand, local manufacturing of spare parts, and was launched through the newly established start-up „Fieldnode“ in May 2022. Equinor estimates that the application and exploitation of AM in their supply chain will save the company around 470 million NOK during 2022.

1. „3D Printing: Hype of Game Changer, A Global EY Report 2019“ https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/advisory/ey-3d-printing-game-changer.pdf
2. „An Additive Manufacturing Breakthrough: A How-to Guide for Scaling and Overcoming Key Challenges“ World Economic Forum White Paper January 2022: https://www3.weforum.org/docs/WEF_Additive_Manufacturing_Breakthrough_2022.pdf
3. „Is 3D printing's potential almost fully formed?“ EY report 2020 https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/manufacturing/ey-is-3d-printings-potential-almost-fully-formed.pdf?download
4. Metal AM magazine: „BMW reports successful integration of automated AM car parts production line“ https://www.metal-am.com/bmw-reports-successful-integration-of-automated-am-car-parts-production-line/

Research Area 1

Work package 1.2

Postdoc Ding Peng has completed his work in the SFI Manufacturing center on additively manufactured multi-material component. We are now working on a manuscript to publish the results from his work.

PhD student Håkon Linga has submitted a paper to the Risø Symposium on Material Science with the title „In-situ X-ray microtomography of interface between additively manufactured aluminium bronze and H13 tool steel".

The results will be presented in the upcoming SFI Manufacturing workshop as well.

We are working on an interesting paper on laser beam remelting of scrap stainless steel for cladding and its comparison with conventional CMT process.

Extensive work has been done in this work, e.g., process parameter development, numerical simulation, microstructure investigation and corrosion testing.

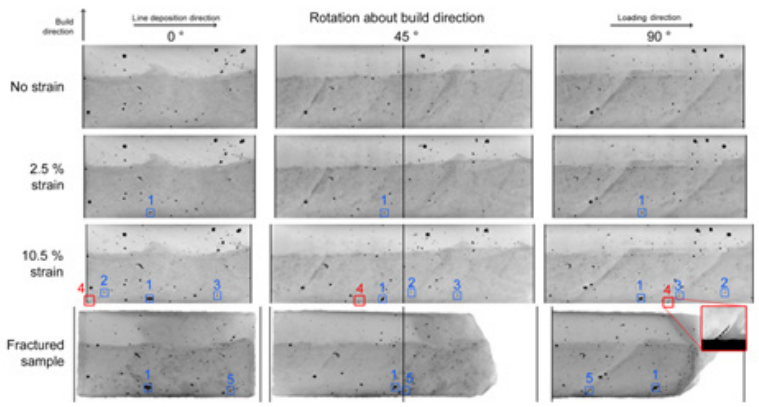

Figure. Minimum intensity projections at various strains and projection angles. X-ray microtomography can clearly show evolutions of pores and initiation of defects with increasing loading.

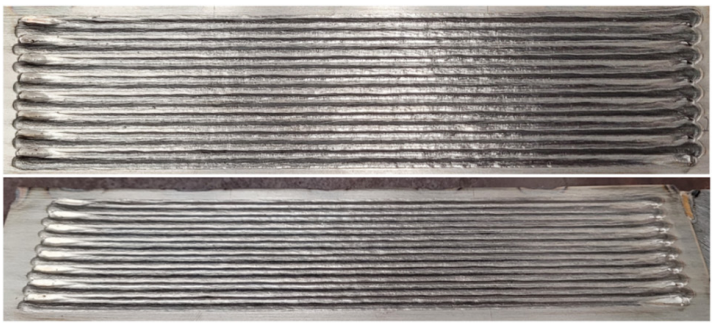

Figure: An example of melt track appearance by laser.

Research Area 1

Work package 1.2

SINTEF is running an internal project to develop experimental and modelling framework for process and material design for multi-material additive manufacturing.

This project is highly relevant and complementary to the SFI Manufacturing project.

In the upcoming workshop, we will present the framework that we believe is valuable for sustainable material development, which is becoming more and more important for circular economy and green manufacturing.

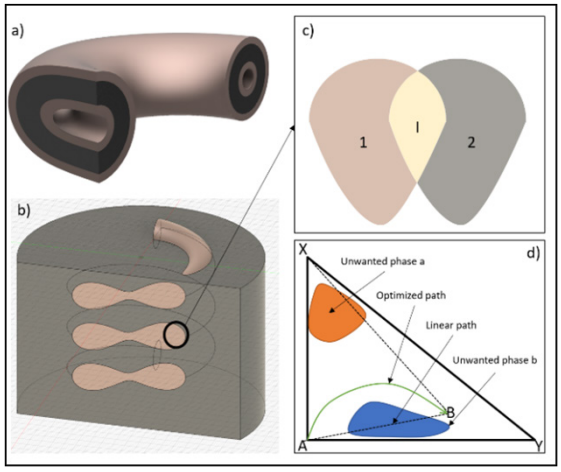

Figure: (a) and (b) examples of multi-material designs. (c) The interface area between two materials. (d) Path from material A to B to avoid unwanted phases.

Research Area 1

Work package 1.3

PhD candidate Chaman Srivastava (NTNU, 2019-2023) continues his work on analysing the degradation processes which occur during the aging of composites products.

In 2021, Chaman has focussed on physical and chemical characterisation of composites which have been exposed to a number of different environments which real composite parts might be expected to experience during their service life, such as extremes of temperature, cycles of strong sunlight and hot and cold water exposure.

These environmental factors may affect the polymer matrix of fibre reinforced composites, resulting in a reduction in the fibre matrix interface strength, and so reducing composite performance over time.

By collecting data on a range of variables and characterising the changes in performance of large numbers of samples, Chaman hopes to build models to predict failure processes of composite parts in real environments.

In early 2022, Chaman successfully passed his mid-term review and is on track for completing his PhD in 2023.

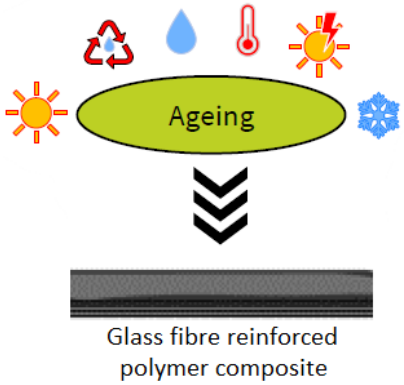

Figure: Chaman Srivastava has investigated the effect of different aging parameters on the properties of glass fibre

PhD candidate Anna-Maria Persson (NTNU 2017-2021) has recently submitted her thesis, with a planned defence in 2022.

Anna-Maria has researched the performance of multimaterial components comprising an injection mouldable thermoplastic elastomer, combined with a harder thermoplastic substrate.

Since both components can be melt processed, this enables two component injection moulding – complex multimaterial parts can be manufactured in a single automated process, reducing manufacturing time and costs.

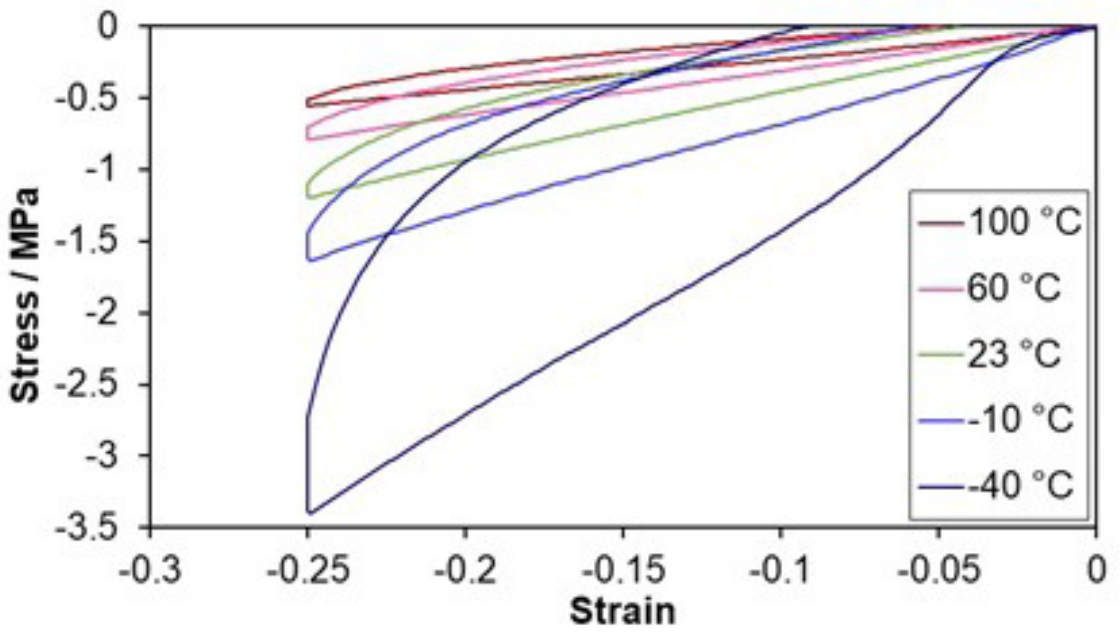

Figure: The effect of temperature on the compressive stiffness of one of the elastomers in Anna-Maria Persson's PhD study. As temperature increases, the elastomer becomes softer.

Being able to melt these polymers also opens up more routes for recycling, simplifying the end of management of the materials at the end of the application life.

One possible drawback of these melt-processable materials is that they can be sensitive to temperature, and so the mechanical properties of these materials was investigated at different temperatures; as with most polymers, the higher the temperature, the softer they become (see figure).

Therefore, it is important to understand how this softening affects applications which might experience high temperatures (for example in automotive applications)

Research Area 3

News from the work packages

Plasto
Plasto has for almost ten years been discussing and experimenting with circular business models in practice.

The main example has been how to use recycled plastics in the production of components of fish farming cages.

This involves exploring collaborations and establishing partnerships across existing value chains.

The related innovation process is seen as unique by the SFI Manufacturing researchers and has therefore been used as a case study for academic publications.

During the workshop on 21th of June researchers, Eli Fyhn Ullern and Sigurd Sagen Vildåsen, shared their reflections on the case study, how it has developed over time, and why it is of interest to the academic community.

Work-in-progress: Environmental upgrading in global value chains
There has been increased attention towards sustainability in all parts of society. The manufacturing industry is no exception. However, how manufacturers, and particularly suppliers, within global value chains, actually work to improve the environmental footprint of their production, remains somewhat unclear.

The motivation for this research article is to uncover how Norwegian manufacturers work with environmental upgrading, which entails improvements related to the product, process, organization or end-of-life that reduce environmental footprints.

Given that many Norwegian manufacturers are suppliers in global value chains, one core question is; what power do Norwegian manufacturers have to conduct environmental upgrading? Preliminary

Assiya's and Henrik's PhD project update
In her PhD project Assiya applies global production networks and global value chain frameworks and the concept of environmental upgrading to understand factors that influence recycling in manufacturing industry.

As a part of the PhD project Assiya works on a paper together with Henrik Brynthe Lund, where they focus on recycling of discarded plastics equipment from the Norwegian aquaculture.

Assiya and Henrik draw upon literature on innovation and global production networks to understand better the potential for improving the environmental footprint of the Norwegian fish farming.

Research Area 3

News from the work packages

Findings from this work point out the importance of physical distance between the recycling actors and fish farmers for developing innovation in form of recycling. The physical distance can influence transportation, increasing costs and environmental footprint of the recycled plastics.

Trust between the recycling actors and fish farmers has also been crucial for the case firm's ability to develop an innovative recycling solution. Both physical distance and trust can be important for actors who plan to develop recycling solutions for plastics from the Norwegian aquaculture.

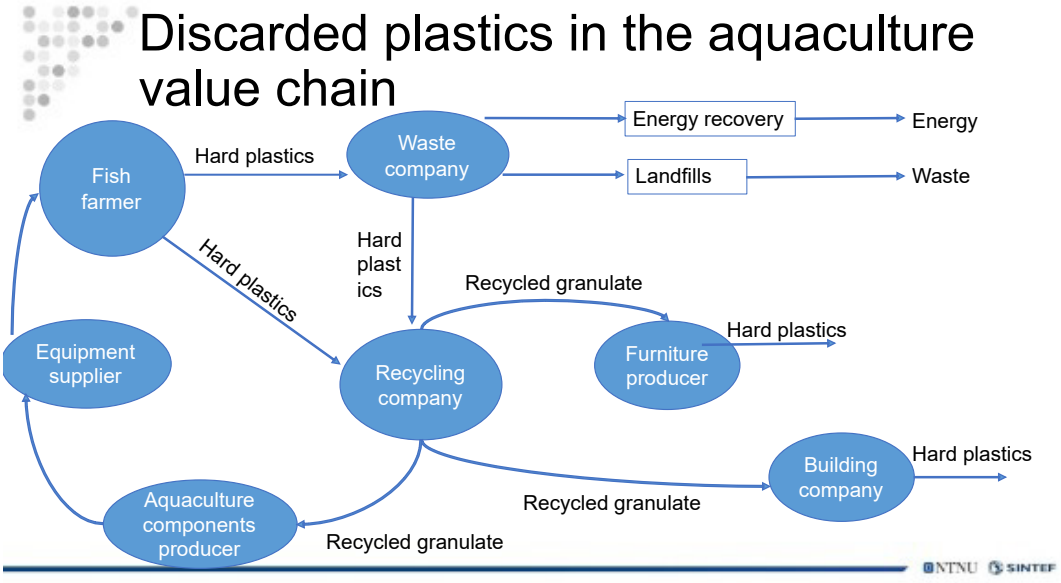

Figure: Henrik Brynthe Lund