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Newsletter

Date: April 3, 2020

The aim of this newsletter is to keep the community up to date with the current research that is being carried out within and related to the centre. This issue of the newsletter is focused on both research area 1) Multi-Material Products and Prosesses, and 2) Robust and Flexible Automation.

In this issue:

sfi Centre for Research-based Innovation

The Research Council of Norway

SFI Manufacturing

A cross-disciplinary centre for research based innovation for competitive high value manufacturing in Norway

Update from the centre management

Challenging situation
The Covid-19 situation is causing a challenging situation for all our partners in SFI Manufacturing, and we do not have a certain overview of the consequences for our centre. However, for the time being the status for the centre can be summarised as follows:

- So far, the activities are mainly according to the work-plan for 2020, and over the next weeks we assume that we can maintain this activity.
- The workshop at Kongsberg Automotive on March 23-24 is postponed to June 8-9.
- All 1-1 meetings with the industry partners are rescheduled to online meetings, and the last 3 meetings are scheduled in April.
- The limited access to laboratories is causing difficulties for some of the research activities and will probably lead to a delay of some deliverables in 2020, with a delivery date in Q3 instead of Q2.
- The PhD and Postdocs are reporting that they for now are mostly ok.
- One PhD candidate had planned for 3 PhD courses this semester but 2 got cancelled.
- NTNU is working on a possible compensation support for PhD's and Postdocs that will be delayed due to the Covid-19.

Contact with the Research Council
The SFI Manufacturing management has been in contact with the Norwegian Research Council and Norsk Industri with in-put on possible actions that can support the centre partners and reduce the operation risk for the centre:

- The Research Council has been asked to accept that the earlier reported in-kind contribution from the partners above the minimum for the period 2015-2019 can be used as a relaxation of the in-kind contribution in 2020 and 2021. This is confirmed ok by the research council for SFI's but not for IPN's.
- The centre has asked for increased financial support from the Research Council, but this has not been approved.
- The centre has asked for a revision of the practice for calculating the hourly rate for in-kind contribution of the industry partners, but this has not been approved.
- The centre has suggested that SIVA increases the support to the MTNC catapult centre for rapid development of online courses for competence building activities for manufacturing industry. We are awaiting a reply to this proposal.

Finally, the Research Council has started a new process for IPN applications with no specific deadline. This means that IPN applications can be submitted continuously during 2020 and there are to be expected 3-4 rounds of grants this year.

We hope you all are coping with this challenging situation and that we can remain a strong nation team for manufacturing also after this crisis.

About the research areas

RA1 – Multi-Material Products and Prosesses
New advances on sustainable, lightweight and high-performance products can be achieved by combining the best properties of different materials, such as the impact toughness of aluminium and weight/strength ratio of carbon composites. This is a major trend for demanding markets such as the automotive, aerospace and maritime industries.

In the first half period of SFI Manufacturing we have focused on selected topics related to design and manufacturing processes of multi-material products. The two main scientific focus areas have been to study different processes of joining dissimilar materials and on topics related to additive manufacturing of metals and polymers. Additive production of large components must be performed "out-of-the-box" using robot manipulator to deposit material along a pre-designed path. This cross disciplinary topic has been investigated together with RA2 (see below).

However, the global trend towards circular economical thinking will have a strong influence on product design including choice of materials. Sustainability in material selection and production processes, including high recyclability of materials in multi-material solutions will therefore become a focus area in SFI Manufacturing in the second half. This cross disciplinary topic has together with RA3 become a central theme in many of the newly started spin-off projects and will be included in case studies relevant for the industrial partners within SFI Manufacturing.

RA2 – Robust and Flexible Automation
The research area Flexible and Robust Automation concerns the novel technologies and methodologies within automation to support innovation processes and advanced work systems in the manufacturing industries.

Novel automations technologies and methodologies, and smart integration of those, open new ways to use automation and robotics in manufacturing systems. However, several research challenges still need to be addressed to release the potential for innovation. Within this research area we focus on generic challenges identified from a mapping at the industrial partners conducted in the timeframe 2016-18. Some examples are bin-picking, safe and efficient motion planning in dynamic environments, "batch size one" robotic assembly, robotic flexibility in additive manufacturing, and effective and safe development of robotic assembly processes. Several of these challenges also link to the other research areas within the SFI.

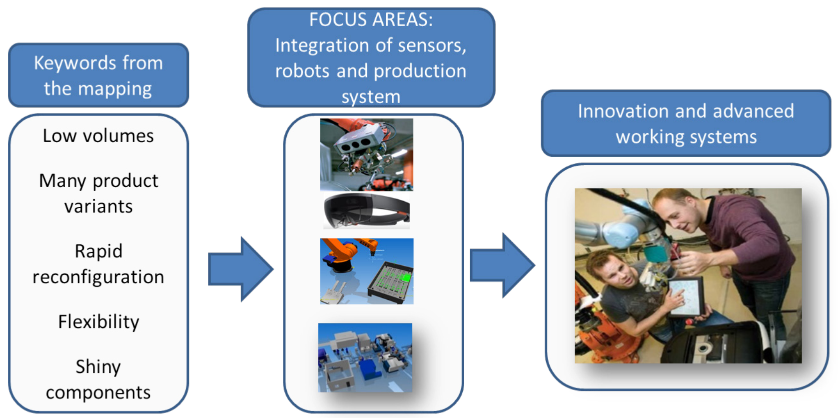


Figure 1 Research Focus: To further develop and link novel technologies and methodologies within automation to support innovation processes and advanced work systems in the manufacturing industries.

RA2 – Update on the research activities

Publicity and publications
A total number of 6 conference papers, one PhD thesis and one journal paper has been delivered in 2019. One of these conference papers will be published in the proceedings from IWAMA 2019, in 2020.

The papers were published at three different conferences and in one workshop. The conferences were "The 7th International Conference on Control, Mechatronics and Automation", "5th IFAC Conference on Intelligent Control and Automation Sciences ICONS 2019" and "International Workshop of Advanced Manufacturing and Automation (IWAMA 2018)". The last conference was held in 2018, but the paper was presented in the proceedings in 2019. The last paper was presented at "1st IFAC workshop on Robot Control (WROCO 2019)". Furthermore, one paper has been published in the IEEE Access Journal.

At last, Mathias Hauan Arbo defended his PhD thesis with the title "On Robotic Assembly and Optimization-Based Control of Industrial Manipulators" in April 2019. A video of Mathias talking about his thesis and research can be found on the SFI website.

Goals and workplan for 2020
Research Area 2 has identified the following goals:

1. Increase degree of automation in manufacturing cells.
2. Provide flexible and robust robot programming solutions in assembly, additive manufacturing, deburring and machining.

The work will focus on three methods. In RA2.1, a method for "Vision algorithms to detect deviation between CAD data and real product data" is planned to be developed. A method for "Planning of robotic operations for low volume production (assembly and deburring)" is a collaboration activity between RA2.1 and RA2.2, while the last method for "Closed-loop robot control for high-quality production (AM and machining)" is the focus of the activity in RA2.2.

These activities will strengthen the research collaboration between institutes involved in RA2 and the collaboration across the RA's (e.g. robotic AM (RA1-RA2) and robotic low-volume production (RA2-RA3). The work will also link research and PhD work closer to cases provided by industrial partners.

SIMS symposium
The International Symposium on Small-scale Intelligent Manufacturing Systems (SIMS) is the leading international forum for academic and industrial experts to disseminate information on the most recent theories, practices and research results in the field of Small-scale Intelligent Manufacturing Systems. The conference will be held on Norwegian University of Science and Technology, Gjøvik, Norway, 10-12 June 2020 or as a virtual event, in the same timeframe.

SFI Manufacturing is one of the hosts for this conference and provides an excellent possibility to PhD students, Postdocs and researches from the SFI Manufacturing to meet with other world leading researches from across the world.

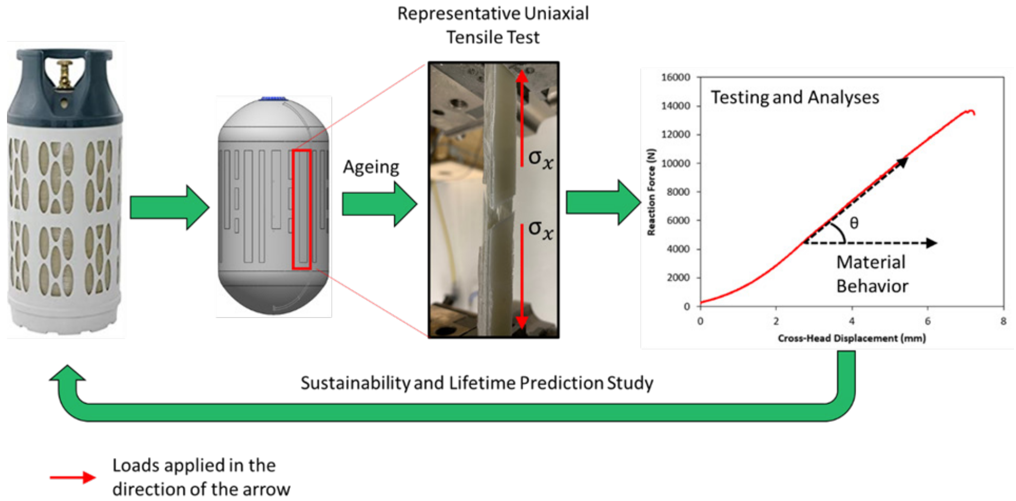
Figure 2. Hosts of the SIMS symposium.

PhD progress reports

RA1 – Chaman Srivastava – Lifetime prediction and structural degradation of polymer and polymer composite components
I am Chaman Srivastava and started my PhD in June 2019, under the supervision of Prof. Sotirios Grammatikos. My PhD work is carried out at the ASEMlab of the Department of Manufacturing and Civil Engineering, NTNU Gjøvik. The work is in close collaboration with industrial partners and is co-supervised by Ben Alcock at SINTEF Industry in Oslo. The main topic of my PhD is lifetime prediction and structural degradation of polymer composite materials.

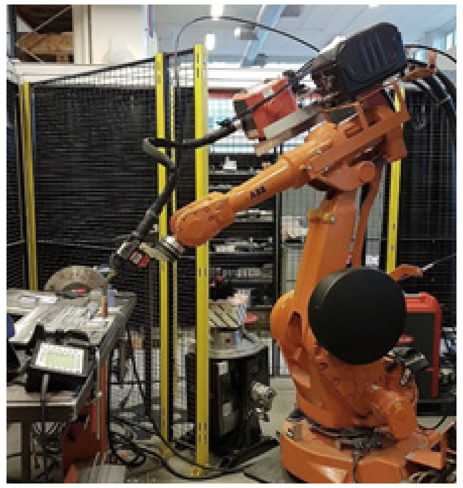
Composite materials are often preferred materials for structural and non-structural purposes due to their high specific properties and resistance to aggressive environments. They are used in a diverse range of applications such as transport (especially aerospace, marine and automotive) and civil engineering (such as bridges, wind turbine blades, cladding systems and off-shore platforms). Although composite materials are widely employed, their lifetime prediction assessment is still a question for the industry. Fibre reinforced composite materials comprise combinations of very different materials, a strong and stiff fibre reinforcement phase held together with a polymer matrix phase. Like all materials, the performance of composite materials can degrade with time. The reinforcement and matrix phases and the interface between them are affected very differently by local chemical and physical environmental factors and the way in which they degrade during use can be multifaceted and difficult to predict. Therefore, the predic-tion of the service lifetime of composite components is highly challenging and requires an understand-ing of the different degradation processes and their impact on the performance of the part.

In my PhD, we will assess different accelerated ageing protocols by closely replicating complex environmental factors like heat, rain and snow at lab scale, characterize the behaviour of the composite material and analyse the failure mechanisms that are observed. The end goal is to create a material database of widely used composite materials for different ageing environments which can be valorised by industry to design their products. The work will also be complemented by numerical modelling to establish a quanti-tative relationship between environmental factors and material mechanics.



RA2 – Linn Danielsen Evjemo – Wire Arc Additive Manufacturing

One way of enabling additive manufacturing (AM) in a large workspace and on a large scale, is to use a robot manipulator to deposit material along a pre-designed path. Overhangs – regions of material built over empty space, without support structures to hold it up – are one of the most basic limitations for traditional AM methods. Because traditional AM methods add material layer by layer either top-down or bottom-up, building structures with overhangs requires that additional support structures are built, and then removed in post-processing. Using the full flexibility of a robot manipulator could allow us to bypass this and build overhangs directly.



Apart from some initial experiments, my work has focused on wire arc additive manufacturing (WAAM), combining a robot manipulator with welding equipment to deposit metal. This work has in large part been done in collaboration with SINTEF Industry, and the focus has been on cold metal transfer (CMT) welding, though the demand for a higher heat input based on material or stage of the welding process has made in necessary to do parts of the experiments using pulsed-MIG welding as well. Both aluminium and the nickel-based alloy Inconel625 have been used to map how material properties affect the resulting build. These results were presented at the IFAC conference on Intelligent Control and Automation Sciences in Belfast in August 2019. The structures were built with a fixed, vertical orientation of the welding gun, not using the flexibility offered by the robot's many degrees of freedom.

In 2020, some additional experiments have also been done using Alloy 59 (also a nickel alloy) in order to map how this material behaves during a semi-continuous build. This seemed to work very well. Considering the cost of both materials and gas, the builds were stopped after between 50 to 70 layers of material deposition. It seemed they could have gone on for much longer without issues related to overheating, at least on a superficial level. Experiments utilizing the full flexibility of the robot to build more complex structures with overhangs are still next on the agenda, and the current focus is to use these methods to build a cylindrical structure with overhang, i.e. with a varying radius.

RA2 – Ingrid Fjordheim Onstein – Robots in deburring processes

I started my PhD in August at the Department of Manufacturing and Technology located at NTNU Gjøvik. Before becoming a PhD, I completed my master's degree in cybernetics at NTNU in Trondheim in 2018. I wrote my thesis about path planning for additive manufacturing using robot manipulators together with SFI Manufacturing where Jan Tommy Gravdahl and Linn Danielsen Evjemo were my supervisors. This autumn I wrote an article on the work from my master that was submitted and later accepted to the 21st IFAC World Congress.

After completing my master's, I thought I wanted to get away from cybernetics and started working as an IT consultant instead. 6 months later I realized how wrong I was and after 6 more months, I started my PhD.

In my PhD, I will investigate how robot manipulators can be used in deburring processes to relieve workers of a repetitive and hazardous task. Robot manipulators are already used in many deburring applications, but for low-volume and high-mix processes, the cost of robotic deburring is still too high. This is mainly due to the long setup/programming time. Cast parts have larger burrs than for example machined parts. The parts also have geometric variations due to the casting process. As a result, it is difficult automate the deburring process. The picture shows a cast part from Mjøs Metallvarefabrikk with large burrs.

This spring, I have been doing a literature review on robotic deburring to find the state-of-the-art and future challenges that should be addressed. The result of the review is presented in an article that was submitted to the 3rd International Symposium on Small-Scale Intelligent Manufacturing. The next step in my research will be to investigate a more flexible and automated path planning method for robotic deburring by combining 3D vision and CAD model of the part. This will be done in collaboration with SINTEF Digital.

RA2 – Andreas Hanssen Moltumyr – Closed-loop additive manufacturing by robot manipulator

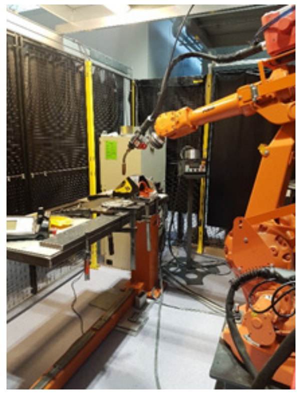
Since starting as a PhD candidate at the department of engineering cybernetics in august 2019, I have had the satisfaction of exploring the various realms of additive manufacturing (AM) and the research being put into furthering its capabilities, like customizability, with the aim of making it a manufacturing system of tomorrow. However, the challenges are many. One of the most severe being the low reliability when thinking in terms of geometric accuracy of deposition. Another challenge is that of manufacturing parts with overhang.

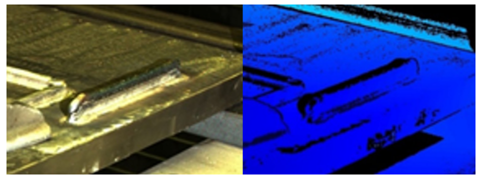
Additive manufacturing has proven to be a great tool for rapid prototyping and have even matured to the point of finding its way into industry for the manufacturing of highly customized parts. However, to make sure that additively manufactured components can serve its purpose, post-process quality inspection of parts outer-surface, outer-geometry and inner-structure is key for industry. Currently, there is a significant research effort directed towards the development of online in-situ quality monitoring for AM. Online in-process monitoring has the capability of reducing material waste and enable time savings by fixing errors online when they happen or by aborting a completely irreparable print before the end. Following this trend in AM research, the aim of my PhD work is to explore the various options for online monitoring and closed-loop control in AM and try to assess the usefulness and challenges of such methods.

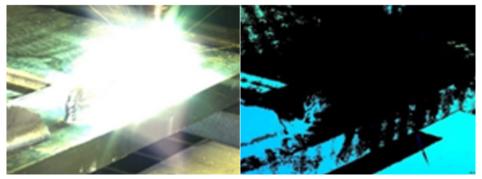
Finishing up the work from my master's thesis in engineering cybernetics from the Norwegian University of science and technology, an article on the topic of fractional-order control was submitted to the 21st IFAC World Congress in November and later accepted.

In March, a short Initial experiment with a Zivid stereo camera (structured light) for geometric measuring in an AM process was conducted with the help of Linn Danielsen and in collaboration with SINTEF Industry. Using the wire arc additive manufacturing (WAAM) technique, a thin walled structure was built layer by layer, stopping the process and capturing a depth image after each consecutive layer. Capturing depth images during the WAAM process was also attempted, but the strong light from the melt pool rendered the structured light method infeasible.

Moving forward, further research into the state-of-the-art on online monitoring techniques and closed-loop control methods for AM will be conducted in order to ensure a solid foundation before development starts.







Relevant research projects

8 out of 10 Innovation project applications last year were granted, and here is a short list and description of each of them:

Short name	Full name	RA..	Project Owner	Industrial partners	Research partners
HASAM	Hypereutectic Alloys of Silicon and Aluminium for additive Manufacturing	1	Elkem	Hydro Aluminium, HyCast	SINTEF Industri SINTEF Manufacturing
The objective is to enable hypereutectic high silicon AlSi alloys for additive manufacturing (AM). A general effect will be to contribute to an increased usage and flexibility of Al-Si alloys for AM and a potential broadening of the market for Al-Si powdered alloys.					
KomVent	Innovative solutions for the valves of the future	1	Isiflo	HV Plast, Industriverktøy	SINTEF Industri SINTEF Manufacturing
The aim is to develop next generation of smart valves and taps manufactured in a plastic composite material. Material selection and design solutions will be key, as well as proper tool design and parameters in the moulding process to ensure a robust process that provides products with good and repeatable properties.					
STRAUSS	Superior Temperature Resistant Aluminium Steering Shafts	1	Steertec	Thune produkter	SINTEF Industri, SINTEF Manufacturing
The project targets an economic, high-quality and high-productivity manufacturing of temperature resistant aluminium steering components for the automotive industry. Presently, no mass-produced aluminium solution can meet the specifications. A successful result will allow car manufacturers to further reduce weight and hence improve fuel consumption and lower CO2 emissions.					
DATAVAR	Closed Loop Data-Driven Manufacturing Variation Management using Industry 4.0	2	Benteler	Ragasco	NTNU SINTEF Manufacturing
The project will utilize large amounts of data collected throughout chains of individual processes in order to optimize the overall capability of complex manufacturing systems. The data will serve as an input to machine learning algorithms and statistical procedures that will learn the hidden patterns between numerous parameters.					
MATE	Mobile Autonomus Tool Exchanger	2,3	GKN Aerospace		SINTEF Manufacturing
MATE represents an "intelligent" agent, an autonomous service robot for everyday tasks for CNC machine operators. The operators will be able to focus on more value-added tasks, while MATE is taking care of machine tending (loading and unloading of workpieces) and transportation of machine tool holders between CNC machines.					
ASaP	Automated measuring and grinding of propeller blades	2	Oshaug Metall		SINTEF Manufacturing
The objective is to develop technology for robotic measurement and grinding of moulded propeller blades. New algorithms are needed for robots to recognize, measure, and efficiently plan and execute grinding movements on propeller blade surfaces.					
Rask Respons 4.0	Next generation value chains for quick response, customised manufacturing	2,3	Gilje tre	Nordic door	SINTEF Digital SINTEF Manufacturing
The project targets innovation solutions for a sustainable and cost-effective development of SME manufacturers of customised products to Quick Response and Industry 4.0 levels. QR 4.0 solutions cover value chain strategies, factory and warehouse implementation, computer-driven human-machine interaction platform, and demo projects.					
WONDREST	Wonderful Circular Rest	3	Wonderland	Møbelringen, Recticel, Måndalen Trevare, Plasto, J O Moen Miljø	SINTEF Manufacturing NTNU
Through the WondRest project, Wonderland will collaborate with partners across the value chain; from subcontractors to distribution and recycling companies. The goal is a new product with a lower environmental footprint than today, and a business model that will take responsibility for the entire life cycle of the product.					

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