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Newsletter #3 RA1

Date: 9th of October, 2017

This newsletter is published prior to each workshop of SFI Manufacturing. The aim is to keep the community up to date with the current research that is being carried out within and related to the SFI. This issue of the newsletter is focused on the research and achievements from the research area RA1 – High structural efficiency products based on multi-materials with robust and adaptive manufacturing processes.

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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

Welcome to the multi-materials research area!

Introduction to the research area RA1

About RA1: High structural efficiency products based on multi-materials with robust and adaptive manufacturing processes

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 two years 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. However, the global trend towards circular economical thinking will have a strong influence on product design and optimal choice of materials taking the concept of Design-for-Disassembly and recycling into account. Sustainability in material selection and production processes, including high recyclability of materials in multi-material solutions will therefore become a focus area of SFI Manufacturing in the coming years.

Among various dissimilar material combinations, the joining of aluminium to steel has had extensive attention, both scientifically and in industry, due to the increasing relevance of lightweight solutions. Within SFI Manufacturing we have identified six different approaches of joining these two metals. One PhD candidate has started investigating the Cold Pressure Welding (CPW) process for joining aluminium to steel, and two PhD candidates are focussing on material structure and properties in the vicinity of the interface, using advanced material characterisation methods and atomistic modelling respectively. Other joining processes we have started to investigate are Cold Metal Transfer (CMT) and a Hybrid Metal Extrusion and Bonding (HYB) technology patented by the partner company HyBond. The last method we have started working on is adhesive bonding.

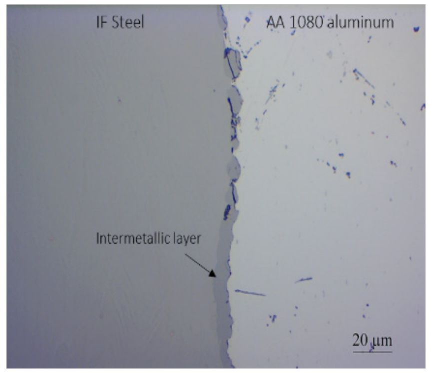

Figure 1. Bonding aluminium to steel creates an intermetallic layer that can be studied with an electron microscope.

Figure 2. Adhesive bond strength in bonding composite laminates is tested in a single lap shear test.

The process of adhesive bonding, either gluing or secondary lamination, is the key to joining thermoset matrix composites: the surfaces cannot be melted so welding is not an option, and through-thickness mechanical bonds (rivets, screws etc) perforate the fibre reinforcements, leading to structural damage. Within SFI Manufacturing, we performed an initial study of physical and chemical parameters of both the adhesive and the surfaces to be bonded in order to understand effects influencing the adhesion and strength of the bond. This work is continued in the recently granted spin-off IPN-project "Joining of composite structures" which is described later in this newsletter.

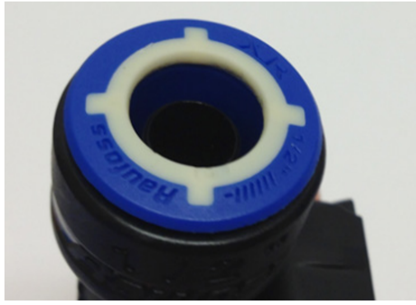

Figure 3. Example of a rubber TPE seal (white) moulded on to a hard-plastic material (blue) in a prototype component made by Kongsberg Automotive.

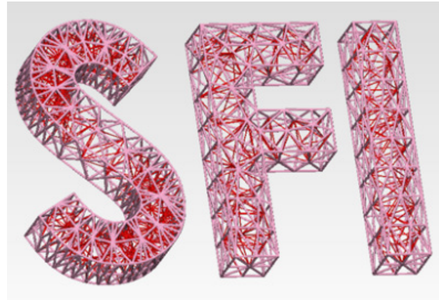

Figure 4. Example of so called lattice structures (truss work) that can be built by AM.

One important industrial method of combining two polymeric materials (e.g. a soft and a hard polymer) in a single product is through 2 component injection moulding. One PhD candidate is studying this process focusing on moulding a group of rubbery materials called Thermoplastic Elastomers (TPE) on to a hard plastic such as Polyamide. This work is closely related to a spin-off project called "Injection moulded solutions for primary and secondary seals in couplings" which is described later.

In addition to more conventional processes of producing multi-material products, we have in SFI Manufacturing a special focus on additive manufacturing as an important enabling production technology alone, or in combination with traditional production methods like forging and casting. In the past few years, the additive manufacturing community in Norway has grown substantially. Nordic Additive Manufacturing AS has received and installed their Trumpf Directed Energy Deposition (DED) cell at the Raufoss industrial park. This machine will be able to make larger metal parts at a much faster rate. The setup was performed in collaboration with SINTEF and NTNU. Also on the powder bed side there have been movements in the Norwegian industry, with Tronrud Engineering doubling their metal printing capacity while at the same time investing in a new polymer based powder bed machine.

Work so far in the SFI has focused on:

- How to design additive production methods using so called lattice structures (truss work).
- What properties are possible to achieve (this activity is closely related to the KPN-project MKRAM).
- Writing a summary of international roadmaps and standards - SFI Manufacturing also contributed in the development of international standards (ASTM and ISO).
- Investigating the possibility of building parts using Wire and Arc Additive Manufacturing (WAAM) technique, i.e., combining CMT and robots. Together with RA2 a PhD candidate is working on robotic control and sensors in such an AM setup.

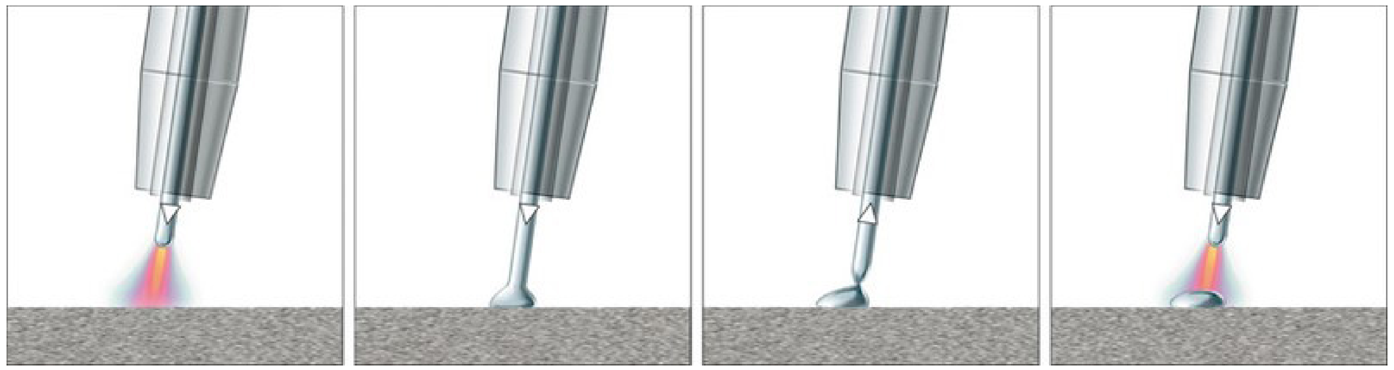

Figure 5. Illustration of the basic principles of Cold Metal Transfer technology.

A look into the world of multi-materials

Examples and results from ongoing research and PhD activities in RA1

Making the impossible possible - Joining aluminium to steel

Joining aluminium to steel attracts extensive attention both scientifically and practically due to increasing interests of lightweight solutions. However, joining aluminium to steel is easier said than done. That is because they literally do not mix well with each other, especially when the two materials get hot. The biggest challenge of joining aluminium to steel is the formation of brittle intermetallic compounds. Controlling or eliminating these intermetallic compounds is the key to producing a sound joint. In SFI Manufacturing, we aim to tackle the challenge of joining aluminium to steel through both fundamental and applied research with industrial case studies. At this moment we are focussing on three different joining processes: 1) Cold Pressure Welding (CPW), 2) Hybrid Metal Extrusion & Bonding (HYB) and 3) Cold Metal Transfer (CMT). CPW and HYB processes are solid-state joining process, while CMT is a fusion welding method. Three involved PhD candidates aim to obtain fundamental understanding of the relationship between joining process, microstructure, interface property and product performance, as illustrated in figure 6.

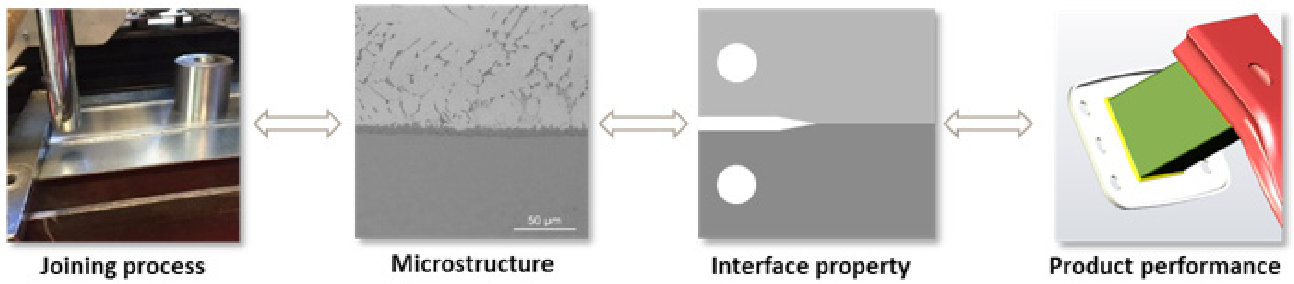

Figure 6. An integrated understanding of aluminium-steel products.

PhD candidate - Siri Marthe Arbo

The aim of my project is to study some fundamental aspects of joining steel and aluminium, two of the most commonly used engineering metals. Individually these metals have desirable properties, so by joining them correctly, we can utilize the best of both worlds. Currently I am conducting experiments where I produce three layered composite sheets by cold roll bonding and I am studying the variations introduced by joining different alloy combinations, variations in thickness and stacking sequence. One of the goals is to understand how the different alloys are affecting the strength of the final joint, and if there are limitations regarding which alloy combinations that can be joined using Cold Pressure Welding (CPW).

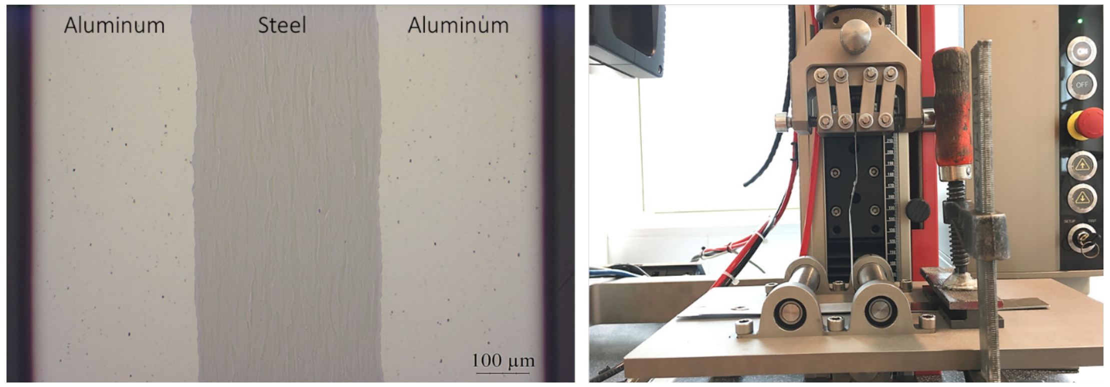

Figure 7. Three layered composite sheets produced by cold roll bonding.

PhD candidate - Tina Bergh

My PhD work aims to characterise the interfaces in joints of aluminium and steel. The first year has been filled with courses, duty work, schools, trainings, workshops and travels. Currently, I am working on sample preparation and characterisation of joints made by three different techniques: cold roll bonding (by Siri Marthe Arbo), hybrid metal extrusion and bonding (by HyBond), and Cold Metal Transfer (by SINTEF). My main tool for characterisation is Transmission Electron Microscopy (TEM). I use TEM to study both the crystal structure and the composition of the joints, down to atomic scale. At the interfaces, I typically find different intermetallic compounds. An example is shown in figure 8. They vary greatly in type and thickness, depending on the joining parameters. To get a thorough understanding of the interface, different TEM techniques are crucial. Another critical part of my work is data analysis. I am currently focusing on programming analysis routines for the large datasets I get from TEM. My goal is to obtain complete characterisation of the interfaces, and ultimately to understand their influence on the mechanical properties of the joints.

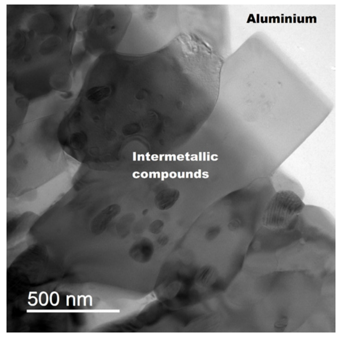

Figure 8. TEM image of intermetallic compounds at the Al side of an interface of an Al-steel joint made by Cold Metal Transfer.

Cold Metal Transfer (CMT)

SINTEF has successfully demonstrated that CMT welding is feasible for joining steel (zinc coated Z275) and aluminium (AA5754), as the galvanised steel plate is wetted by this braze-welded joint, while the aluminium melts. Detailed metallurgical and mechanical investigation shows that a 5 µm thick intermetallic compound can be achieved, which will give satisfactory mechanical properties through a tensile shear test. Figure 9 shows an example of a microstructure of aluminium-steel CMT joint, and figure 10 shows the result of the tensile shear test.

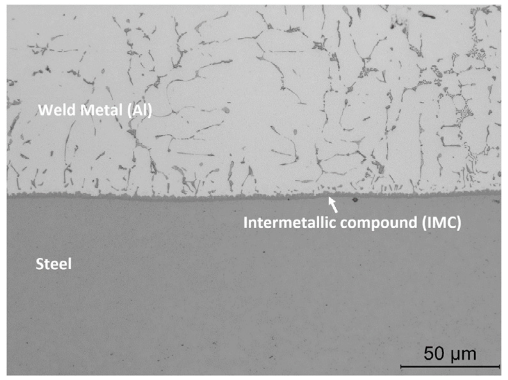

Figure 9. Microstructure of aluminium-steel CMT joint.

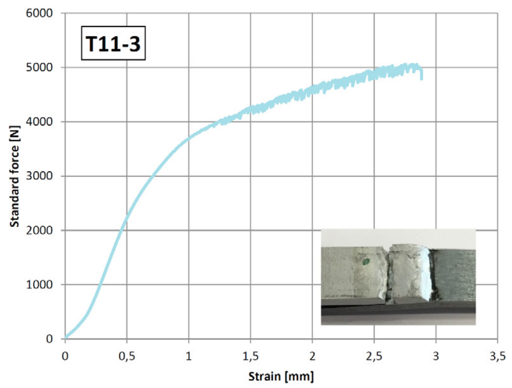

Figure 10. Tensile shear test of aluminium-steel CMT joint.

Multi-scale modelling

Integrated Computational Materials Engineering (ICME) is an emerging discipline that can accelerate materials development and unify design and manufacturing by the integration of materials information, captured in tools, with engineering product performance analysis and manufacturing-process simulations. It is a computational approach to design products, the materials that comprise them, and their associated materials processing methods by linking material models at multiple length scales, i.e. multi-scale modelling. Multi-scale modelling links the structural response described by continuum mechanical approaches to constitutive material morphology and properties obtained on smaller scales (like crystal plasticity, microstructure, sub-microstructure (e.g. dislocation interactions), atomistic and electronic scales) through different types of models (e.g. continuum, discreet, statistical, mean field microstructure, thermodynamics, force field and ab initio models). In line with the experimental work described above, the focus has so far been on the joining of aluminium and steel, both wanted (welding) and unwanted (galling).

Welding

The activity on welding has been the main focus of PhD candidate Muhammad Zeeshan Khalid in close dialog and collaboration with SINTEF. Figure 11 shows a scanning precision electron diffraction (SPED) image (from the PhD work of Tina Bergh) of the intermetallic phases created in the joint when welding an aluminium 5754 plate to a Zn-coated Z275 steel using a 4xxx AlSi3Mn filler wire. Our aim is to gain further insight in the details of the bonding properties of such a joint. Density Functional Theory (DFT) will be used to calculate important properties of the different phases and interfaces, like elastic constants, work of decohesion and interfacial energies. However, since the observed structure is far too complex to be studied by atomistic modelling, a simplified representation of the joint is shown in figure 12, neglecting subgrain structure, defects and additional phases except aluminium, Fe_4Al_{13}, Fe_2Al_5 and steel. Furthermore, since aluminium alloys are dilute and the Z275 steel is iron-based, we will model aluminium as pure Al and the steel as pure Fe without considering additional alloying elements, vacancies or secondary phases.

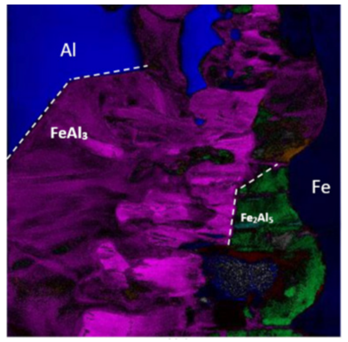

Figure 11. SPED image by Tina Berg of the intermetallic phases created when aluminium to steel.

Figure 12. A simplified representation of the joint, indicating the three main interfaces Al/Fe_4Al_{13}, Fe_4Al_{13}/Fe_2Al_5 and Fe_2Al_5/Fe.

After these initial simplifications, the first step was to set up good atomistic models for Fe_4Al_{13} and Fe_2Al_5, which are rather complex phases with partial occupied sites, many atoms in the unit cell and low symmetry. After these were determined, models for the Al/Fe_4Al_{13}, Fe_4Al_{13}/Fe_2Al_5 and Fe_2Al_5/Fe interfaces were built. Unfortunately, experimental orientation relationships between these phases were not possible to extract from the experimental SPED data. But the fact that the interfaces are faceted, indicates that they are coherent and that representative interface models can be constructed by searching through all possible orientation relationships for coherent interfaces with small misfits. However, because of the large number of atoms in the unit cell of Fe_4Al_{13} and its low symmetry (space group number 12 in International Tables), the number of non-equivalent orientation relationships became too large to be handled by our old tools for determining such models (even when running it with 40GB of memory on NOTUR). Hence, a new Python module for building interface models was developed, that efficiently reduce memory requirements by pipelining and analysis of crystal symmetries to reduce the number of cases to consider in several steps. With the initial version of this new tool, the interface models shown in figure 13 were created.

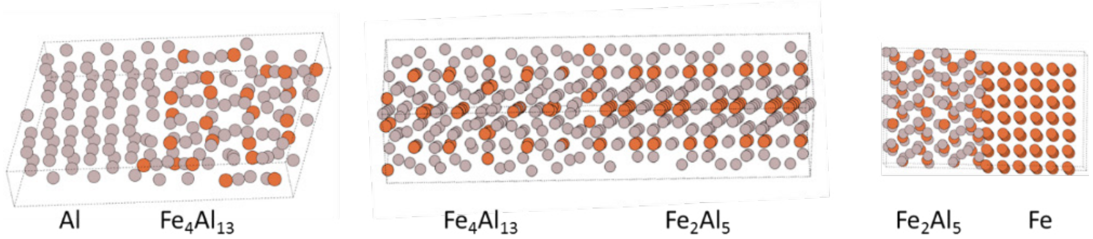

Figure 13. Periodic atomistic interface models for the Al/Fe_4Al_{13}, Fe_4Al_{13}/Fe_2Al_5 and Fe_2Al_5/Fe interfaces created with the new interface builder.

Galling

Since galling is a challenge in many relevant industrial forming processes and is true multi-scale in nature, driven by contact mechanisms occurring at several scales, from macroscopic to atomistic, it has been identified as a good case for SFI Manufacturing. A parallel activity has therefore been started in SINTEF to define a multi-scale modelling approach for galling. Wear and galling mechanisms are strongly related and depend on the contact conditions. An accurate prediction of galling and wear requires accurate modelling of the contact. Many contact models have been developed to predict wear behaviour, while a limited number of models have been able to predict galling. A report has been written describing a multiscale modelling approach of contact with attention to the prediction of galling. It introduces numerical models at the different contact scales as well as at scale transitions. The great potential of the multi-scale modelling approach is shown to qualify the galling phenomena in forming process. It shows that it can be used to investigate the galling mechanisms at micro-scale and nano-scale and to qualify the galling behaviour at macroscale. The influences of material compositions on the adhesion is described at the nano-scale through the computation of surface energy and the energy of separation. The influence of the surface roughness of the workpiece is described at meso-scale. The galling behaviour on the macro-scale is described as function of the contact pressure and sliding length determined by finite element simulations, and captures the surface properties at meso- and micro-scale. Figure 14 illustrates the main components of this modelling approach.

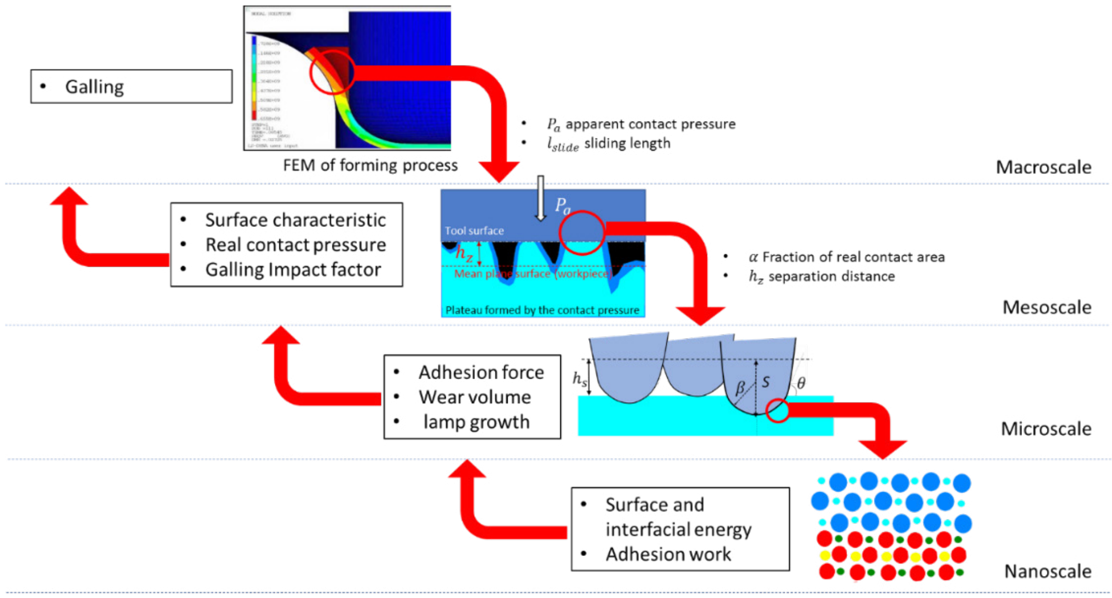

Figure 14. Illustration of the multi-scale modelling approach of galling.

PhD candidate - Muhammad Zeeshan Khalid

One year ago I started my PhD work on the atomistic modelling of multi-material interfaces. The first year was full of new experiences, learning, course work, summer school and travelling to Trondheim. The aim of my PhD project is to develop realistic atomic interfaces for Al-Fe system to provide useful insights about atomistic level changes during Al-Fe welding. The most common sequence of intermetallic compounds along the interface reported in the literature is given as: Al/$FeAl_3$/Fe_2Al_5/Fe. I am currently aiming to develop this interface system to predict the overall system stability and describe the bonding nature and electronic structures of intermetallic phases. My goal for this study is to develop a basic understanding about IMPs and their role in the strengthening of Al-Fe joints. The most challenging part is to develop different atomistic interfaces, but I am lucky to have experienced scientists in my supervision team. Jesper Friis is currently helping me in developing these interfaces using edge-to-edge matching techniques.

Topics in Additive Manufacturing

Additive Manufacturing (AM), also referred to as "3D printing", is growing in Norway and the SFI Manufacturing consortium is a part of this growth. During the last year there has been a growth in interest for industrially mature processes in both metal, polymers and ceramics. However, the materials are limited, so many research projects are working on extending the reach by applying studies on relevant materials. An example of this is the study on Super Duplex Stainless Steel by SINTEF Raufoss Manufacturing and Statoil, or the study on Haynes 282 done in MKRAM. These steps are time-consuming and costly, but important to be able to reap the benefits that these new processes bring.

Directed Energy Deposition

Directed Energy Deposition (DED) is an additive manufacturing process in which focused thermal energy is used to fuse materials by melting as they are being deposited. The last year we have seen investments in this technology in Norway, with Nordic Additive Manufacturing AS in Raufoss acquiring a Trumpf Laser cell, Westad acquiring a machine from Metco Oerlicon and the University of Agder getting a DMG Mori Lasertec machine. We have also seen a growth in the use of Wire Arch Additive Manufacturing (WAAM) at SINTEF Materials and Chemistry, which has lead to an investment in an extra Cold Metal Transfer welding machine. This will be an important link to the work of PhD candidate Linn Danielsen Evjemo. To strengthen the knowledge of this technology at NTNU, SFI Manufacturing invited all partners, students and professors related to this field to a lecture at Gløshaugen. From France we had invited Frédéric Le Moullec of BeAM, a well-established producer of DED-machines. BeAMs DED-machines are the first machines that have made certified parts for critical moving jet-engine parts for aircrafts. Mr. Le Moullec (figure 15) explained that their machines did not rely on feedback during operation, and hence all operations were pre-programmed through a normal post-processor. Furthermore, the feedback from sensors is also post-processed to see if there could be reasons to doubt the part quality. He also presented some of the limitations and challenges that they are working on. With the purchase of a machine, he invited us to become an alpha partner having access to lots of know-how and being invited to research projects.

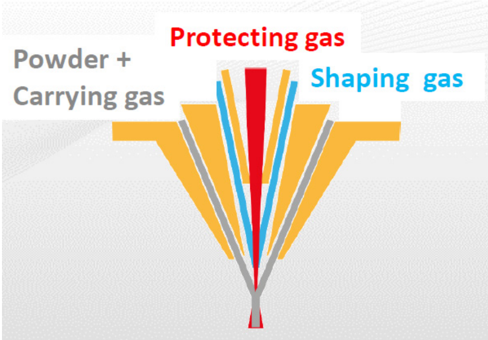

Figure 15. Frédéric Le Moullec answering questions about the control mechanisms in their DED-machines.

Additive manufacturing standards

The latest standards that will become available will have a strong focus on technical design guidelines for powder bed fusion. There are separate standards for metal and polymer powder bed in this case. We will deliver a "design guideline" report to the consortium soon. When considering using the AM-processes, there are many potentials to take into account, but these are at the top of the list: customization, lightweight, internal structures, functional integration, designed surfaces and material specific options. To achieve the potentials of the AM methods one should consider using software to help topology-, structural- or functional integration. However, the material options in all the processes are still limited. The development of new materials is both time demanding and expensive, which limits the industrial implementation. Due to the high material efficiency of the processes, it is tempting to use a more expensive material in AM than is needed. For example, titanium grade 5 and maraging steels are often used instead of lower quality metals.

Simulation of AM methods

SFI Manufacturing has together with NTNU and Ecole Centrale de Lyon contributed on analytic and numerical prediction models of AM-processes. The first process to be studied was a laser based DED. The study emphasizes the temperature gradient, the cooling rate and the melt pool size. The analytical model (figure 16) is based on the moving heat source assumption, while the numerical model is built including the multi-physics of the laser processing. This included the phase transformation. The results of the two simulations are compared with experimental work. Both approaches are validated and gave acceptable results. The analytical model appears to be good enough to predict the critical cooling rate, which is the key factor for an online process control. Before it can be used, it still needs to be extended in a 3D-geometry. The numerical model gives information on the workpiece, especially on the melt pool and on the temperature distribution, but with a long computation time. An analytical model gives valuable information on the temperature with good precision in a short computation time. The laser power and scanning speed's influence on the temperature and cooling rate are investigated and the correlations are established. A workshop was arranged at the 12th of September in Trondheim, inviting Dr. Omar Fergani from Siemens Digital Factory in Texas, USA. The day was used to understand and discuss the AM simulation solutions that will become available from Siemens PLM in the coming year. Teeness, NAM, Westad, Tronrud, Statoil, Zenith systems and Digitread all attended the meeting that was held by Vegard Brøtan at SINTEF Raufoss Manufacturing. Many of these companies already work with NX, and there was great interest to be able to validate the parts and process through the solutions that Dr. Fergani displayed. Their first software will enter the market at the end of 2019, but we are able to be a part of the beta-testing phase, which we believe will give us a huge advantage. Reseach projects on this topic are in the planning phase.

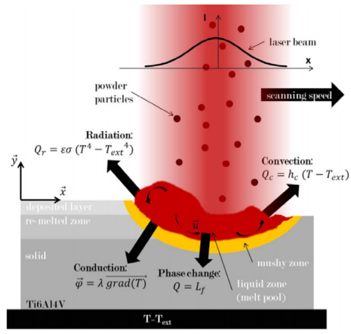

Figure 16. Heat transfer and configuration of the DMD process.

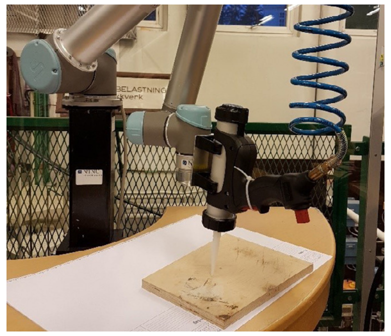

Figure 17. Proof-of-concept experiment using a robot manipulator and caulking gun.

PhD candidate - Linn Danielsen Evjemo

I started my PhD work in December 2016 and I will focus on large-scale, robotized additive manufacturing (AM) using industrial robot arms and Cold Metal Transfer (CMT) welding. I will try to see if it is possible to combine the large workspace of an industrial robot arm with the flexibility and relative affordability of traditional AM methods. More specifically, the aim is to deposit metal along a given trajectory, building the final metal structure gradually as the manipulator tracks this reference trajectory. Combining CMT welding with robotised AM has the potential to build metal structures from scratch, not just perform robotised welding. This technology could also be useful in repair work, for example when having to close holes and tears in metal surfaces on ships or other large structures. AM by a robot manipulator would free us from having to build structures layer by layer, which is the most common approach for traditional AM methods. This could allow us to print larger, and more complex geometries. Several robot manipulators could potentially also work simultaneously, with different materials. Figure 17 shows a robot manipulator being used to additively build a part using an electric silicone gun to extrude material.

Additive manufacturing of elastomers parts

There is a wide range of elastomer (rubber) materials in use today, but it is thermally crosslinked (vulcanised) rubbers that are mostly used in demanding engineering applications such as seals, car tyres and anti-vibration couplings. The reason for this is their excellent chemical and thermal stability together with their resistance to abrasive wear and permanent deformation (so called creep or compression set). Additive manufacturing of various hard and soft plastics has been developed in recent years. Plastic parts made by AM typically use melt processing to produce thermoplastic polymer parts, or UV curing to chemically crosslink thermoset polymer parts. However, these AM techniques are not suitable for use with the types of crosslinked elastomers routinely used in demanding applications, and no commercial AM solutions exists for these materials.

Figure 18. Tensile test samples of elastomers produced by additive manufacturing. Top: A multimaterial test specimen produced by combining two different elastomers during one additive manufacturing technique. Bottom: A single material elastomer test specimens.

In SFI Manufacturing, the principle of additive manufacturing engineering rubber samples is being developed. Early results show that homogenous planar structures can be created using an experimental AM technique applied to conventional engineering elastomers. In addition, the AM technique is well suited to combining different elastomer materials in a single process. Even at this early stage, multi-material samples have been produced which combine different types of elastomer in one AM process (see figure 18 above). This allows the creation of continuous parts with local variations in materials and properties within a single manufacturing step. As well as planar parts, simple three dimensional parts have also been produced using this technique, and so there is potential for the production of parts with more complex geometries.

Other topics

Reversible adhesives

Adhesive bonding is often the best method to join very dissimilar materials, such as thermoset composites with metals. Commercial adhesives are types of polymers which are designed to bond well to different surfaces and provide mechanical load transfer, while tolerating the application environment. While many commercial solutions exist for adhesive bonding, they can be problematic when it comes to the end of life of the part because adhesive bonds are difficult to separate. This complicates disassembly, which is a usual requirement for recycling of multimaterial parts. In an internally funded project, SINTEF is investigating new chemistries which can function as adhesives but also include a switchable nature. This means that the adhesive is designed to hold two surfaces together, but also have the potential to release the bond when triggered by a certain debonding stimulus. There are significant challenges in developing these materials, and laboratory testing to prove the potential of new chemistries is ongoing at SINTEF Materials and Chemistry.

Atomistic modelling of adhesive bonds

The characterisation of adhesive bond performance is often performed using standardised tests of bonded test pieces which are then mechanically separated. These tests tend to be very specific to the surfaces used and geometries of the bonds, so the information obtained is only applicable to a particular bond. Therefore, it is attractive to develop models which predict the performance of adhesives, based on the chemistry at the interface. A new internally-funded research project at SINTEF Materials and Chemistry aims to develop models of the adhesive-substrate interface an on atomic scale. It is expected that such models will allow the prediction of the interactions between different combinations of adhesives and substrates, and provide guidance on which surface preparations may give the best surfaces for adhesive bonding in real applications.

PhD candidate - Anna-Maria Persson

I started my PhD at the 1st of February 2017. My study is related to the field of mechanical properties of thermoplastic elastomers in injection moulded components and is closely related to the IPN-project SPETT, which is described later. I started my PhD with experimental studies of the elasto-visco-plastic response of a novel but commercialised thermoplastic elastomer prepared by vulcanization. One significant aspect is sample preparation and geometry (figure 19), and another is handling and treating the experimental data (strain) output. As the experimental methodology in itself is a target for the PhD, a selected few more materials will be studied subsequently. Materials models are intended to be calibrated and verified as well, primarily for a selection of published material models. Currently I am immerged in 10-15 years of publications of rubber and elastomer material models. One major challenge is to adequately describe the complex mechanical response with a model also suitable for industrial use. Figure 20 is an example of one characteristic of elastomer mechanical response.

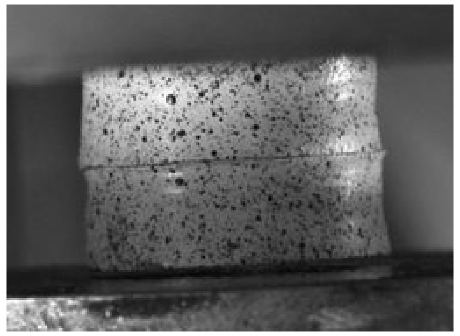

Figure 19. Speckle patterns for digital image correlation.

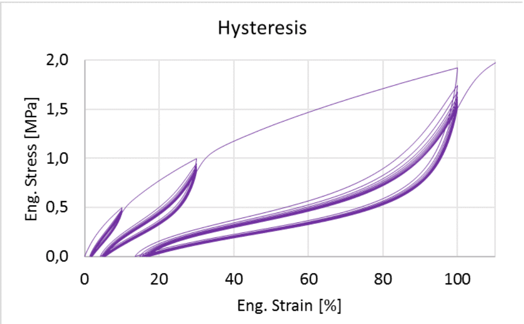

Figure 20. A visco-plastic-elastic type of response during cyclic tensile loading.

Ongoing projects

Examples of some relevant "border area" projects

SPETT - Injection moulded solutions for primary and secondary seals in couplings

2016 - 2020

Partners: Kongsberg Automotive, Raufoss Water & Gas, HV Plast, SINTEF Materials and Chemistry, SINTEF Raufoss Manufacturing

The project's primary goal is to develop material and design solutions making it possible to integrate primary and secondary seals in next generation couplings using two-component injection moulding. R&D challenge: To be able to mould seals by two-component injection moulding instead of mounting o-ring seals the traditional way. It is also relevant to mould seals onto brass couplings using injection moulding.

SamKomp - Joining of composite structures

2017 - 2020

Partners: Brødrene Aa, Mundal Båt, Palfinger Marine Safety, Hydrolift, Brimer, CSUB, Reichhold, DIAB Norge, Hans Clausen, FiReCo, Maritim Engineering, SINTEF Materials and Chemistry

The mail goal is to establish systematized knowledge with the aim of developing new solutions for joining and fastening structures in Fiber Reinforced Composite (FRP) materials: Solutions that are safer and more reliable as well as cost-saving in relation to today's production technology. R&D challenges are e.g. related to material selection and joining method (gluing or secondary lamination), production process of laminate and panel, and design of joint.

OPTIMALS - Optimal design and production of lightweight and high-performance aluminium-steel structural components

2017 - 2020

Partners: Benteler Automotive, Hydro Aluminium, HyBond, SINTEF Materials and Chemistry

The main goal of the OPTIMALS project is to enable multi-material solutions for high-performance aluminium-steel structural components with a total reduction of weight and manufacturing cost. The project will aim to achieve a measurable weight reduction (5-10%) for 2-3 automotive components while keeping or improving specific structural requirements.

Galling in Aluminium Forming

2017 - 2020

Partners: Raufoss Technology (owner), SINTEF Materials and Chemistry, SINTEF Raufos Manufacuring

The main objective of the GALF project is to optimise coating and lubrication solutions under consideration of tool geometry and process parameters, towards an innovative tool design for a more cost-effective aluminium component production, allowing higher productivity by a reduction of galling.

MKRAM - Material Knowledge for Robust Additive Manufacturing

2016 - 2019

Partners: GKN Aerospace Norway, Kongsberg Automotive, Nammo Raufoss, OM BE Plast, Sandvik Teeness, SINTEF Materials and Chemistry, SINTEF Raufoss Manufacturing

The aim of the MKRAM project is, in short, to understand the effective material properties of parts made by the AM processes mentioned above. This includes mapping and understanding the repeatability, i.e. the variation in properties from part to part, from machine to machine, and with different materials and powders. There are several challenges related to AM of structural parts, i.e. mechanically loaded parts.

NextMoldMaker - Added value through establishing a value chain for producing mold tools with additive manufacturing

2018 - 2021 - Delivered project proposal

Partners: Skriverform, IV group, Raufoss Offshore, Hexagon Ragasco, Kongsberg Automotive, HV Plast, Tronrud Engineering, NAM, Westad, NTNU MTP, SINTEF Materials and Chemistry, SINTEF Raufoss Manufacturing

The main objective of the NMM project is to establish a working value chain in Norway for the production of optimized tools through utilizing additive manufacturing. Previous results have shown that powder bed fusion is a hot candidate for cooling and venting optimization, but there is no working value chain in place to produce the tools. Furthermore, it needs to be investigated if DED has a future in repairing and improving tool surfaces and in multi-material tooling.

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