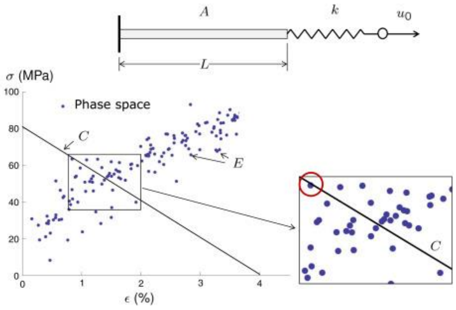
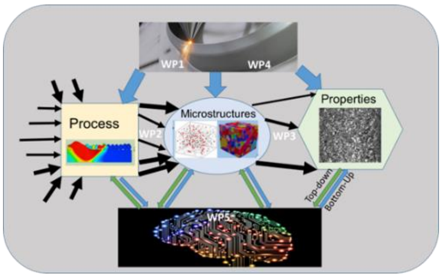
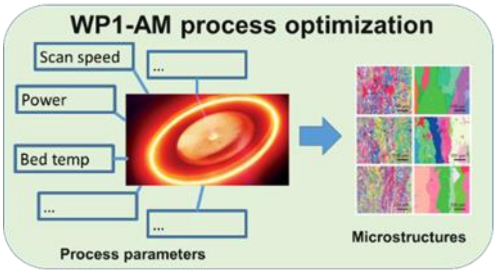
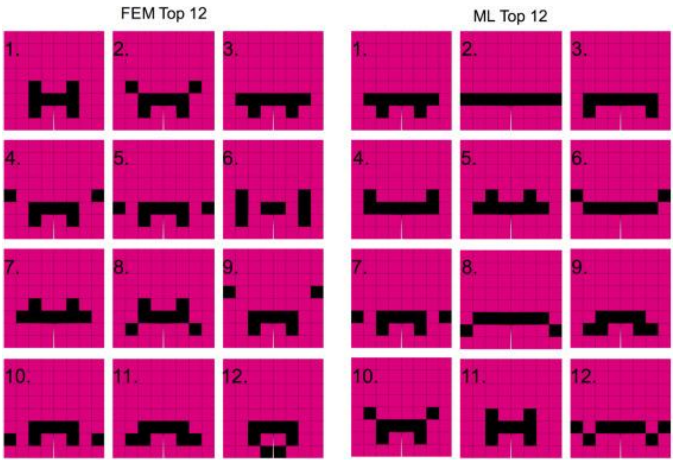
2018-2019 “Anvendt mekanikk” project/master topics

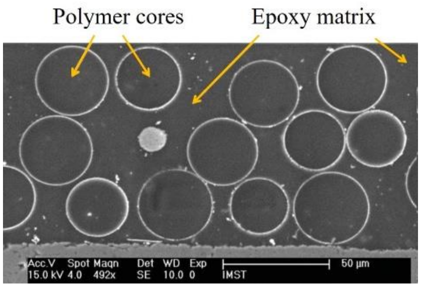
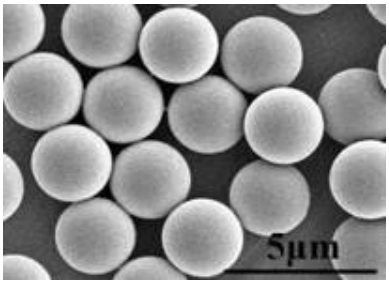
1. Data-driven computational mechanics
2. Machine learning based additive manufacturing (3D printing)
3. Machine learning based material design
4. Anti-icing technology and ice adhesion mitigation
5. Metal coated polymer particles for novel applications

Title	**Data-driven computation-Data Science to structural analysis**
Supervising team	Professor Zhiliang Zhang Cooperation with Professor Michael Ortiz at Caltech, USA
Background	Material constitutive law, deformation compatibility and force equilibrium are the three fundamental principles in mechanics (so-called KLM principles in Norwegian), with the first one being empirical and the last two exactly satisfied regardless of materials. Material modelling is a challenging task. The classical practice has been to calibrate empirical material models using observational data and then use the calibrated material models in finite element analyses. **Data-driven computing (DDC)** is a new computational technique developed by Caltech. In DDC, the calculations are carried out **directly from experimental material data** and pertinent compatibility and equilibrium conditions, thus bypassing **the empirical material modeling** step of conventional computing altogether.
Illustration	
Aims	The aim of the project study is to get familiar with the new computational method and find the advantages and disadvantages of the new method by comparing with the classical method. In the master study, the new method will be applied to structural analysis of selected two-dimensional and three-dimensional structures.
Methods	Numerical simulation.
References	T.Kirchdoerfer, M.Ortiz, Data-driven computational mechanics, Computer Methods in Applied Mechanics and Engineering, Volume 304, 1 June 2016, Pages 81-101.

Title	**Predictive Additive Manufacturing (3D printing) by FEM simulation and Machine Learning**
Supervising team	Professor Zhiliang Zhang and Jianying He Adjunct Associate Professor Jim Stian Olsen, Aker Solutions, jim.stian.olsen@akersolutions.com
Background	Effective manufacturing is of undeniable national importance. Additive Manufacturing (AM) is a revolutionary technology with possibility of 3D printing any material, any shape, any quantity and in any fields, without the need for specialized tooling. However, unlike the matured manufacturing methods, today we can 3D print, but we do not know and cannot predict what kind of materials properties we will obtain. In other words, the current AM is not predictive! This lack of control of the resulting properties severely hinders the rapid exploitation of the AM. Therefore, an opportunity is widely open and there is an urgent need in establishing AM specific process→ microstructure → property/performance relationships, which are the key to the success for any manufacturing technology. There are many parameters affecting the process – performance relations. Machine learning methods have been used in a variety of applications but so far have found limited, if available, use in relation to additive manufacturing. Before any machine learning method can be applied, its algorithms should be trained against a training data set. In the so-called supervised learning which is relevant for the proposed project, the training data consists of a set of input values (e.g. process input parameters) as well as a corresponding set of output values (e.g., materials property values). In this project, COMSOL or ABAQUS will be used to geberate the data. With these training data, the machine learning algorithm will identify a correlation that can make accurate predictions about the output values that will be associated with new input values.
Illustration	 
Aims	The work will comprise of a significant literature review and numerical simulations. The aim of the project study is to make preliminary models using COMSOL or ABAQUS and generate data. These data will be further used as training data set for machine learning to be used in the master thesis to derive the correlation between the input parameters and output parameters.
Methods	COMSOL or ABAQUS + machine learning algorithms
references	https://link.springer.com/article/10.1007/s00466-015-1240-4 https://link.springer.com/article/10.1007/s00466-018-1539-z https://www.additivemanufacturing.media/articles/how-machine-learning-is-moving-am-beyond-trial-and-error

Title	**Machine learning based composite material design towards exceptional properties**
Supervising team	Professor Zhiliang Zhang Dr. Senbo Xiao, NTNU Nanomechanical Lab
Background	As modern engineering applications require superior mechanical properties and versatile functionalities, tuning composite designs has become a key factor in materials development. Two or more base materials can be combined in particular architectures to create a new material with distinctive properties overcoming the limit of each individual material. For example, incorporating softer constituents into brittle materials can alleviate stress concentration, leading to tougher and stronger composites. However, searching for the optimal designs of composites is extremely challenging due to huge number of possible material and geometry combinations. Recently, it has been shown that the material design problem can be solved by combing the traditional finite element method with machine learning algorithm to accurately and efficiently predict mechanical properties of optimal composite systems.
Illustration	
Aims	The project study focuses on literature review and finite element modelling. The master study learn to apply the machine learning and finite element method to material design for selected properties.
Methods	COMSIL or ABAQUS + machine learning algorithms
References	https://www.sciencedirect.com/science/article/pii/S2352431617301256 https://arxiv.org/abs/1801.07337

Title	**Anti-Icing: Ice Adhesion Strength testing and simulation**
Supervising team	Professor Zhiliang Zhang and Jianying He PhD student Sigrid Rønneberg
Background	Ice and frost often cause inconvenience and hazards for the daily life of human beings. Ice removal techniques are costly, energy inefficient and environmentally hazardous. Ice removal might be in the form of de-icing or in the form of anti-icing, which focuses on preventing ice accumulation. A passive anti-icing method removes the accreted ice without supplying external energy to the surface, and might function for several years without supervision or maintenance. There are three main pathways to achieve anti-icing surfaces, namely the removal of water before freezing, the delay of ice nucleation and the reduction of ice adhesion strength. Due to the inevitable formation of ice for long exposures in low temperatures, the most realistic anti-icing strategy is the use of super-low ice adhesion surfaces. Such a surface has an ice adhesion strength low enough so that the ice is shed from the surface due to its own weight and natural processes like wind. The ice adhesion strength depends on many factors, including the surface structure and the microstructure of the ice. Different types of ice are created in different atmospheric conditions, and these types of ice behave differently when adhering to a surface. As of today, there are no available standards for the creating of ice types or their removal, and each research group develops its own methods.
Illustration	
Aims	This project will expand on recent results from the NTNU Nanomechanical Lab, where it was found that different types of ice display different ice adhesion strength [1]. This difference is most likely due to the differences in micro-structure of the ice. The project will reproduce experiments performed at the Anti-Icing Materials International Laboratory (AMIL) in Canada here in Norway, and further investigate the properties of the ice types to see if the cause of the difference may be determined. Research questions may include: •Are the ice types created at NTNU comparable with those from AMIL? •Effect of type of ice on ice adhesion strength measured with NTNU Lab? •How does the ice types behave on different surfaces? The project is intended for both master project and master thesis. The student will be a part of the Department of Structural Engineering, in cooperation with the Department of Civil and Environmental Engineering.
Methods	Testing and simulation
References	1. Rønneberg, S., Laforte, C., Volat, C., He, J., Zhang, Z. The Effect of Ice Types on Ice Adhesion. Submitted. 2. He, Z.; Xiao, S.; Gao, H.; He, J.; Zhang, Z., Multiscale crack initiator promoted super-low ice adhesion surfaces. Soft Matter 2017, 13 (37), 6562-6568.

Title	**Metal coated polymer particles for novel applications**
Supervising team	Professor Jianying He and Zhiliang Zhang Adjunct Professor Helge Kristiansen, Conpart AS, helge@conpart.no
Background	Conductive adhesives are an integral part of electronic systems such as LCD screens, solar cell modules and car electronics. Micron-sized polymer particles with nanoscale metal coatings are an important component in conductive adhesives. Norwegian industry, Conpart AS produces polymer particles in the size range of 3-30 µm. The particles are coated with different metals such as nickel, gold and silver depending on the application. The thickness of the coatings is generally 30-300 nm. Conductive adhesives are an integral part of electronic components such as LCD screens, solar cell modules and car electronics. Micron-sized polymer spheres with nanoscale metal coatings are an important component in conductive adhesives. Using the Norwegian Ugelstad method, Conpart AS produces polymer spheres in the size range of 3-30 µm. The spheres are coated with layers of metals such as nickel, gold and silver depending on the application. The thickness of the coatings is generally 30-300 nm. Understanding the electrical, mechanical and thermal properties of these spheres is critical to optimizing their function in application.
Illustration	 
Aims	The subject of the proposed project/master's thesis will be using multiphysics finite element modelling to understand the coupled mechanical, thermal and electrical properties of individual core-shell structured spheres, especially the effect of coating thickness and surface roughness. The student will closely collaborate with PhD candidates, the other master student in experimental test, and our industrial partner Conpart AS. The program used for multiphysics simulation will be COMSOL.
Methods	Finite element simulation by COMSOL multiphysics
References	1. Bazilchuk M, Pettersen S R, Kristiansen H, Zhang Z L, He J Y, Electromechanical characterization of individual micron-sized metal coated polymer particles. Journal of Applied Physics, 119 (2016) 245102. 2. Pettersen S R, Nagao S, Kristiansen H, Helland S, Njagi J, Suganuma K, Zhang Z L, He J Y, Investigation of thermal transport in polymer composites with percolating networks of silver thin films by the flash diffusivity method. Journal of Applied Physics, 121 (2017) 025101.