Annual Report 2017

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SFI MOVE

Marine Operations in Virtual Environments

SINTEF NTNU

sfi Centre for Research-based Innovation

MOVE SFI Marine Operations

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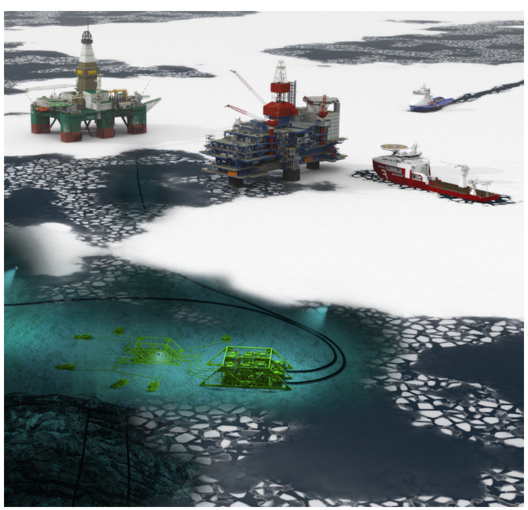
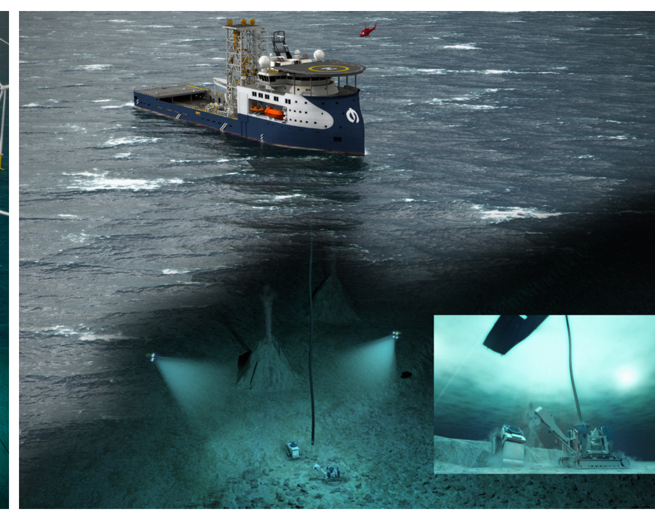
World leading position within demanding marine operations

Photo: Sunnmørsposten, Staale Wattø

Our vision

Photo: Sunnmørsposten, Staale Wattø





Our vision

To establish a world leading research and innovation centre for demanding marine operations.

Simulation has been used for decades to test the physical aspects of marine operations. Simulators are used to train crew to perform demanding operations. Next generation technology has the potential to provide Virtual Prototyping to pre-test marine operations, including the human component. Cutting-edge interdisciplinary research will provide a bridge between industrial needs, innovation and research.

Research
Our goal is to take a world leading position within demanding marine operations.

Innovation
Our goal is to put the industrial partners in front of defining needs and potential for innovation and business.

Education
The research shall lead to theory and new methods for education as well as training of professionals.

Arena
The goal is to establish an arena for research and industrial cooperation within demanding marine operations.

Objectives

The SFI centre shall support the entire marine operations value chain by developing knowledge, methods and computer tools for safe and efficient analysis of both the equipment and the operation. The developed methods shall be implemented in simulator environments to pre-test marine operations including the human component.

The SFI centre shall support the innovation process of the marine operation value chain through active involvement by industry, thus improving the competitiveness for Norwegian marine industry.

The centre shall:
- Achieve all-year subsea operations installation and service
- Perform safer and more cost-efficient operations
- Support innovation in existing and emerging ocean industries

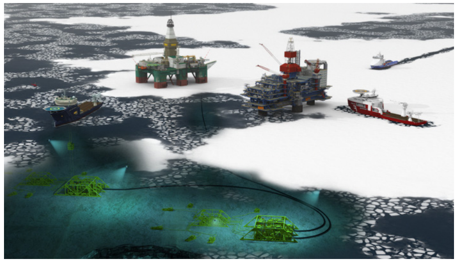
The idea is to optimize operations, from planning to execution, by better understanding of the responses. This is a simulation-oriented approach where models are re-used throughout the value chain.

- System development and design
- System integration and configuration
- Ship and ship equipment
- Operation planning
- Crew Competence and Training concepts
- On-board systems
- Operation execution
- Learning

Business areas

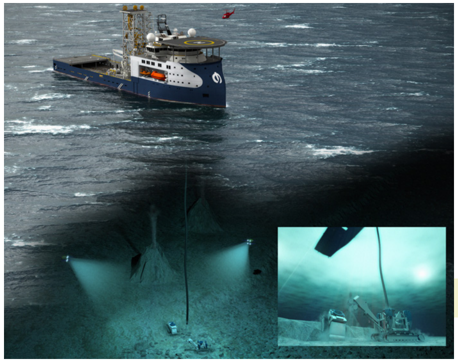
The business areas focused on in 2017 are:

- Demanding marine offshore operations as at ultra-deep water, all-year availability, or arctic areas



- Installation and maintenance of offshore wind

- Subsea mining



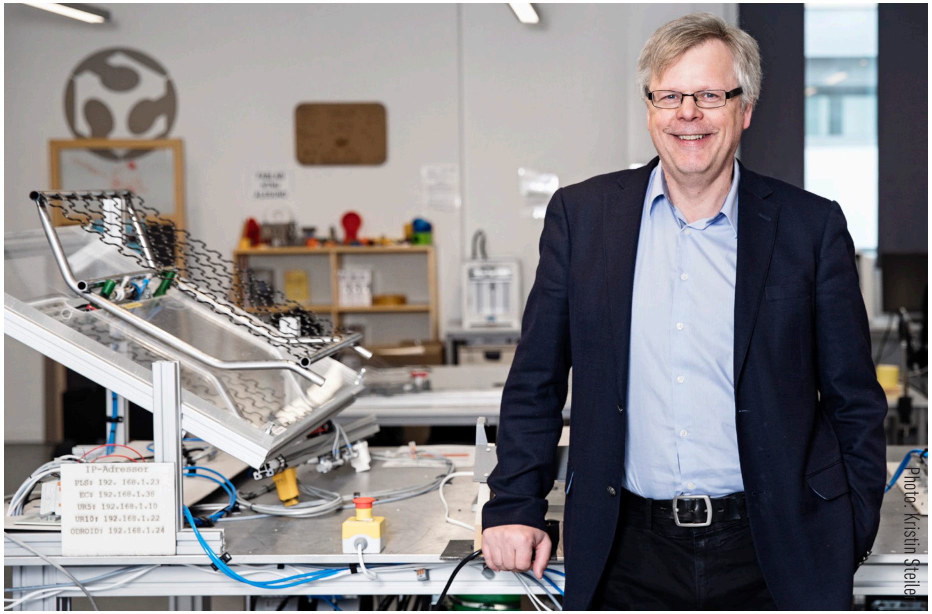
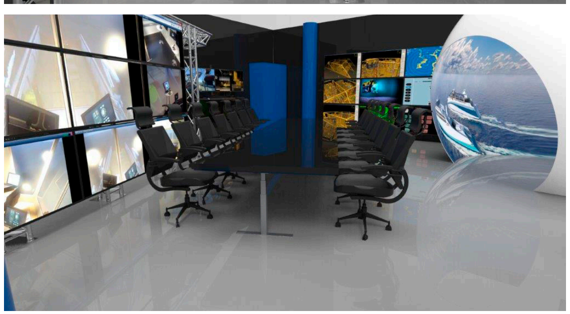
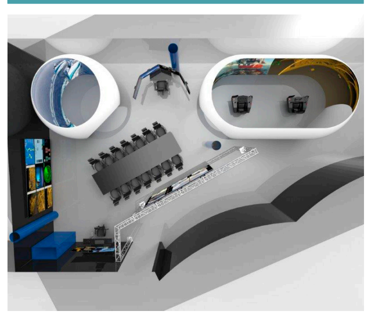


Photo: Kristin Steile

Directors' report

Professor Hans Petter Hildre is the leader for SFI MOVE





Norway has a long coastline and a continental shelf that is six times larger than the mainland and constitutes a third of the European continental shelf. It has major oil and gas resources, rich areas for fishing, excellent conditions for fish farming, as well as offshore wind and a leading position in the ocean industries. 70 % of Norwegian export is from ocean-based industries. Marine operation is a core of development of this industry.

The offshore oil and gas industry have paid a lot attention to cost reduction during the last 2-3 years. We have seen significant restructuring of the offshore support business and efforts reducing costs have been a top priority. In spite of the tough economic situation the industry is in recovery and we can see increased activity and optimism. SFI MOVE is trying to balance between activities that can enhance the competitive strength in short-term and long-term strategic research efforts.

Low-cost innovative installation of Wind Power Systems

Wind installations in the Europe Union (EU) grew 20% in 2017, with 15.68 GW installed across the region. With a total net installed capacity of 169 GW, wind energy remains the second largest form of power generation capacity in Europe. Offshore installation rates doubled from 2016, adding 3.15 GW and leading to a cumulative 15.8 GW of capacity. Still, a new record installation rate for offshore wind farms is expected in 2019.

We are all proud of Statoil's installation of Hywind Scotland, the first floating wind farm in the world. The turbines have started deliveries of electricity to the Scottish grid and the project is a great success for the teams at Statoil.

In recent years, there have been significant cost reductions in both the onshore and bottom fixed offshore wind sectors. Floating wind sectors are expected to follow a similar downward trajectory over the next decade, making them cost competitive with other renewable energy sources. Statoil has an ambition to reduce the costs of energy from the Hywind floating wind farm to € 40-60 €/MWh by 2030.

Turbines are getting bigger and bigger and presenting challenges regarding achieving cost effective installation. SFI MOVE is committed to continuing our work to contribute to ideas and technology to reduce costs of installation and maintenance of offshore wind installations.

Installations are normally carried out with a jack-up ship and with high-lift cranes lifting the individual parts of the offshore wind turbine in place one by one. In total, this is 5 individual lifting operations. SFI MOVE is working with a concept installing the subsea part of the installation (the spar) first and then assemble the tower, turbine and blades in one unit. A new installation concept was worked out in 2017. An installation platform that can move in relation to the ships (and ship movement) is designed. This platform connects and holds both the tower and spar and allows controlled assembly. A ship hull is developed and a crane based on robotic technology on the platform is sketched. Preliminary simulation models are made and proof of concept will be carried out in 2018.

Safe – All-year – Effective subsea installation and service

In the development of offshore oil and gas fields, more and more of the fields are utilising subsea technologies. An increasing number of subsea wells and trees in operation both at the Norwegian Continental Shelf as well as in other regions for offshore activities can be seen. Today a number of fields are also being assessed for life extension, which also contributes to an increased number of systems in operation as the average years in service increases. The successful "subsea factory" installation at Aasgard also opens for new advanced and comprehensive installation projects. This also leads to an increase in the volume of maintenance of subsea facilities and wells in the years to come.

The objective of SFI MOVE is to facilitate marine operations taking place in a commercial and cost efficient manner and thereby contributing to positioning the Norwegian Maritime industry towards the market of such operations worldwide. As subsea field developments are getting more extensive, there is an increasing need for all-year marine operations. All-year operation will have a significant impact on both technology, operational procedures, cost, and will require very different solutions depending on the environment in which you operate.

There is a need for new methods, systems and equipment to achieve the defined objective. Our aim is to establish a virtual prototyping (VP) approach for subsea operations. The following topics have been focused on:

- The first Marine Operation Forum was held in 2017 with the goal of agreeing on performance indices. With these indices, the performance of vessels for subsea lifting operations can be assessed. A multi-criterial methodology to assess the performance of marine lifting operations is suggested.
- A case study for lift-off and water entry, splash zone crossing and further lowering was performed on board Normand Vision which was performing template installation in the North Sea. Results from the case studies are a key to understanding stop criteria and for validation of simulation models.
- Hydrodynamic forces during deployment of complex seabed structures are uncertain due to lack of hydrodynamic data. SFI MOVE has collected hydrodynamic data of various structures and geometries by systematization of data in the literature and results from excisting experiments. Additional hydrodynamic experiments are performed to cover a wide range of structures. A guideline for experimental and numerical modelling of the structures is made.

Exploration of Technologies to Develop Seabed Mining as a New Business Area

The mining industry has a large growing resource potential if moving from onshore to offshore. Present challenges also creating offshore opportunities include: Future lack of onshore resources, rare earth material challenge, geopolitical positioning, conflicting societal interests (environmental damage vs business). Large volume of resources most likely available both inside/outside national waters, very high uncertainty regarding value of resources. In Norwegian waters alone, an NTNU study estimates low value USD 75 bn. No upper limit. SFI MOVE has focused on the design of lift systems to allow efficient lift of minerals from the seabed to the ship.

Simulation Technology and Virtual Prototyping as a Common Approach from Design to Operation

We are facing a substantial technology shift in digitalising industrial processes. We will see new methods of designing ships, equipment and operations as well as crew training. In other words, virtual ships and virtual operations. Ship designers are at present developing real time energy management systems, vessel health management systems, remote control systems and autonomous ship systems. Numerical real time behaviour models are a precondition for an effective development of such systems. This shift will move simulation from a verification point of view to a design and operation point of view. We can see the following key benefits of this development.

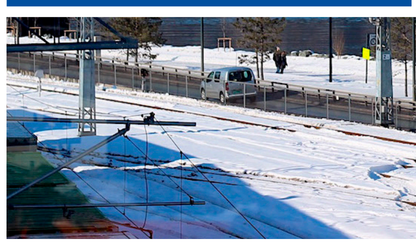
- Transform the industry to a simulation and performance oriented operation approach.
- Increase innovation speed by fast prototyping of ships and operations
- Verification of operations including human factors
- Reduce cost by re-use of models during the process from preliminary investigations to execution of operations

The primary project objective for SFI MOVE is to develop an open, standardized framework and architecture for system simulation and virtual prototyping, which will be a new platform for product development, training and cooperation in the maritime industry. A key to achieving such functionality is an open framework, standardized interface and generic models to be shared in the industry. In the summer of 2017, partners in SFI MOVE, Rolls-Royce Marine, DNV GL, SINTEF Ocean and NTNU launched a project developing a common open

simulation platform. The platform includes an open source simulation core, modelling and interface standards, maritime reference models and APIs. The intention of the open source principle is to enable wide adoption and usage of the core, and by this effectively implementing a new maritime industry standard.

We must be on the international scene to succeed

Text and photo: Kjersti Lunden Nilsen



After SINTEF Fisheries and Aquaculture merged with the research environment in Marintek in 2017, Vegar Johansen has been the director of an activity which at present has nearly 350 employees. According to the enthusiastic Northerner, the co-operation with the research environments in Ålesund are decisive for SINTEF Ocean now going on the international scene on an even wider scale.

He started at SINTEF in 1998, and has long experience from the industry, particularly from SINTEF Fisheries and Aquaculture. Since 1999 he has participated in several research projects in connection with his old job.

His education is within cybernetics, and his primary area has always been fisheries and aquaculture.

«In spite of having the dialect, I didn't know anything about it when I started!», he says in ringing North Norwegian.

We meet him at his office at Tyholt in-between two other meetings that day.

In addition to hectic meeting activity, at the moment he is busily engaged in the submission of a supplementary analysis for Ocean Space Centre, and participation in several development projects.

How has the first year been after the merger with Marintek?
«It has been exciting, rewarding and very demanding, but also a lot of fun! Several cultures, systems and industries were to be joined, but we feel we are beginning to see results.»

What strategies are you working with in order to reach the objectives of continuing Norway's leading position in marine-technical and biomarine research?
«We are working in line with the government's strategy, which is based on the global drivers. The need for food, energy and transport will increase, and the solutions shall contribute to the readjustment of Norway. Our technology is world-leading, and we shall contribute to the increase of that lead», says Mr Johansen and takes us on a tour of the harbour basin at Tyholt.

Founder spirit

According to the director of SINTEF Ocean, Norway has a founder spirit that is completely unique, and in his opinion that gives us some advantages.

«Everything will be about the sea in the future, and there Norway has an enormous position», he says.

Why has it become like that?
«80 percent of Norway's population lives along the coast, and it is there we have created an industry! And in one or another magical way we have managed to invest in education-building in this country, thanks to the fact that we made some clever moves during the post-war period. We managed to develop an industry.»

And here SINTEF has played a central role?
«Yes, we have absolutely contributed», is the Director's modest reply.

He is clearly more comfortable with talking about the ripple effects of co-operation with other actors than accentuating his own activity in front of other people.

Co-operation across the entities

One of his causes in the future, and after the merger with the other universities, is to unite the good forces.

«We must be close to where it happens, and ready to turn the knowledge towards where the challenges are, namely, in the ocean. And it is also here that the great potential for growth lies», he emphasises.

What do you think is contained in growth?
«That is a good question, but it is about constructing systems that manage to unite the many tasks and challenges we face», says Mr Johansen enthusiastically.

«Sustainability will be the whole foundation of what we will be working with from now on, whether you are working in oil and gas, energy or aquaculture», he adds.

With many actors in the same network, busy working days with hectic meeting activity and not least participation in a range of development projects, he is on the go and juggles between different roles and places.

Vegar Johansen has the other of his two permanent offices in the old Findus building at Brattøra in Trondheim. Here the new SINTEF Ocean is surrounded by several other companies in the same industry.

«Closeness to others in the industry definitely means something, and there is a very large potential for co-operating across the entities», says Mr Johansen.

He admits that he likes having a lot of things on the go at the same time better than diving down in one single professional field.

«I am probably the type of person that likes best to have an overview and see things in context», he says, and takes us outside the office at Brattøra, where new technology buildings and office landscapes are popping up like toadstools at the moment.

Advanced ocean technology

«The development in the maritime industry is incredibly exciting now! We must use the whole ocean in the correct way, and that means playing as a team», he assures me.

That brings us naturally over to Ålesund and the many research environments there.

How is the co-operation with SFI MOVE in Ålesund, where SINTEF Ocean is a partner?
«Firstly, I must mention the people in Ålesund, and the culture! There are no obstacles, they see only opportunities, and they are rock hard business people! At the same they are not alien to sowing small seeds in the neighbour's garden.»

He is clearly fascinated by the ways of the people of Sunnmøre.

«I don't know why it's like that, and how they manage it, but I have observed it, and seen it in practice. And they are awesome at seeking out possibilities when they experience adversity.»

According to Mr Johansen it is therefore not so strange that NTNU looked at Ålesund when they were going to change the university structure.

«It's quite natural, both can draw very good benefit from each other in the years ahead. We need even more heads that can find solutions together.»

Rock hard business people

Co-operation with business there is something that the new Director boasts about without restraint.

He also mentions Henning Borgen, the new Director for SINTEF Ålesund, who is an extremely important bridge builder between the various environments.

What results and ripple effects do you see after the establishment of SINTEF Ålesund?
«Quite clearly there are strengthened bonds between Sunnmøre and Trondheim. There has also been an efficient channel where the industry regionally has expectations of us, and the dialogue has been much better.»

On-board support is an important effort concentration for SFI MOVE in Ålesund. What significance does this have for Norway and the rest of the world?
«SFI MOVE is a fantastic project. The on-board support system will be decisive for being able to carry out advanced maritime operations in the future. And efficient operations are critical for finances and safety.»

«Technically, the systems are based a lot on technology and knowledge that has been developed for design of systems, with an additional element that has forged a stronger bond to the operator and the people in the operations», he continues.

He praises SFI MOVE for the way they have kept the glow and enthusiasm going despite readjustment and demanding times, and are looking forward to continuing the co-operation.

«A centre for research-driven innovation is a place where you can generate new ideas. In Ålesund we have all the assumptions for building the bridge that is needed to connect the research with the industry in an even better way», he adds.

Bases on a SINTEF Ocean perspective, which professional area is Ålesund best at?
«They have inconceivably many competent environments, and are extremely competent at integrating the systems. Just look at how they translate knowledge into large technological systems, and put this in to innovative simulation models – it is enormously important bearing in mind all the demanding operations they work with», commends Mr Johansen.

Complete eco system
We stroll along the canal at Brattøra. The very first glimpse of Spring sun is in the air as we look out over a dead calm sea – and have a chat about boats.

«A lot of ships in the future will not have crew on board, and many of them are not developed yet», says Mr Johansen enthusiastically.

And refers to that the Trondheimsfjord was declared as Norway's first test area for autonomous ships in 2016, which has now been included in the Ocean Space Centre concept.

«This binds us even closer to the research environments in Ålesund, and it will become a part of a larger infrastructure from which we can draw benefit together», he says animatedly while he points to one of the crewless test boats that is lying alongside the quay.

Mr Johansen talks enthusiastically when he shows us round Brattøra where after a while we stop by the harbour basin surrounded by Rockheim, Pirbadet, the Norwegian Environment Agency, the conference hotel Clarion and soon also the new zero emissions building Powerhouse which at present is under construction for Entra eiendom.

What is the largest gain by co-operating with other environments?
«There will be a much more complete eco system, and the distance is much shorter between the industry and what was previously the University College of Ålesund. We work here with the whole process from basic research to completed industry», says the proud Director of SINTEF Ocean.

«This is also of great importance regarding Norway's position internationally», he adds.

«Norway also supplies technology to the whole world, we are not only suppliers of oil and fish, but also all the surrounding technology, and it is there both we in SINTEF and the SFIs come into the picture.»

«Both the industry and the research must co-operate closely home in Norway, and if we are to really succeed, we must reach out to the international environments. It is there the great development possibilities lie», says Vegar Johansen in conclusion.

Innovation

Hans Petter Hildre

The idea of the SFI scheme is to promote innovation by supporting long-term research through close co-operation between R&D intensive companies and prominent research institutions.

It is a challenge to achieve both good research and stimulate corporate innovations. The method is to facilitate alliances between enterprises and research groups. Researchers are training in the field to get insight in the business community and are encouraged to transfer research based knowledge and technology.

The Industrial Advisory Group is responsible for setting up an Innovation Plan. The idea is to bridge the gap between industrial needs and research activities. The Industrial Advisory Board met in Ålesund on 26.09.17.

The following new ideas were described as business cases.

- Access system from ship to floating and fixed structures
- Remote control of operations
- Subsea operations from submersible vessels
- Giga-moon-pool
- Active subsea lifting frame
- Crane structure to force modules through the splash zone
- On-board tool for subsea lifting
- Design for workability
- Floating dock for offshore wind assembly and installation
- Wave and tide energy
- The "Digital Ocean Space" at Breisundet

The industrial advisory group decided upon the following projects in 2018.

- Exploration of Technologies to develop Seabed Mining as a new Business Area
- Innovative Installation of Wind Power Systems
- On-board decision tool for subsea operations
- Design for workability

On-board decision tool for subsea operation is a new project merging results from previous projects Safe – all year – effective subsea installation and Service and Simulation technology and virtual prototyping. The motivation for the project is to increase the weather window for marine operations by giving on board advice as a result of real time calculation and evaluation of the critical responses. Historically, the operational limits for various marine operations have been limited by a wave height level (Hs). Such a limiting criteria is often based on assumptions/ experience with existing vessels/ lifting platforms. To increase weather windows, approaching a close to all-year availability of lifting platforms, the operational limitations need to be assessed carefully based on the real time measured vessel motions, crane system motions/forces and realistic load models for the lifting objects in various phases of a lift. Predictive simulation and analytical tools based on the above monitored real time data resulting in on board tools guiding the vessel operators is key.

Research Projects

Project 1 – OW: Low Cost Installation and Maintenance of Fixed Offshore Wind Structures – was completed in 2016.

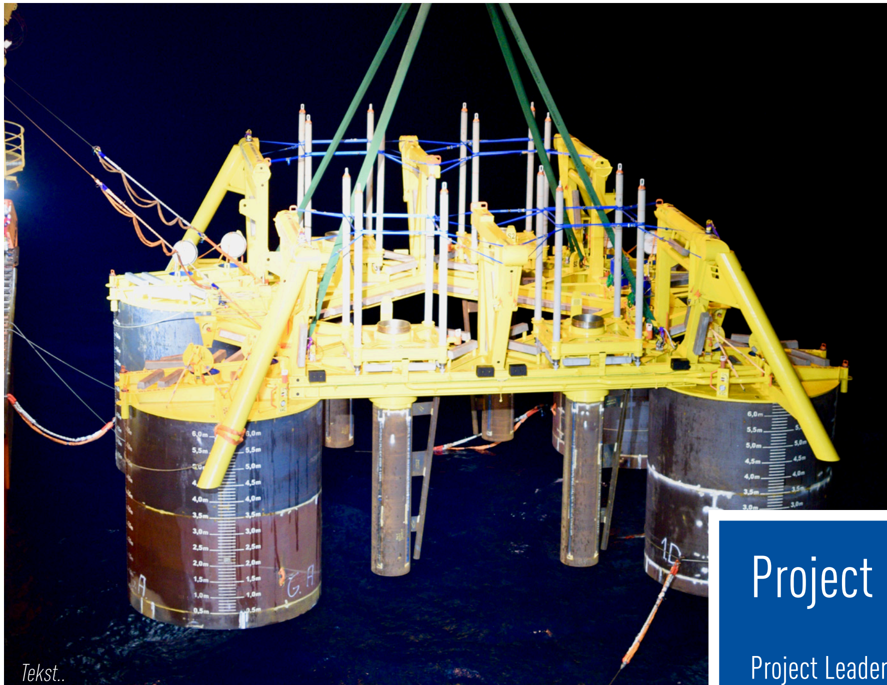
Active projects in 2017:

Project 2 - Subsea: Safe – All Year – Cost-efficient Subsea Operation

Project 3 - Simulation technology and virtual prototyping as a common approach from design to operation

Project 4 - Seabed Mining: Exploration of Technologies to Develop Seabed Mining as a New Business Area

Project 5 - OW: Installation of Offshore Wind Power Systems



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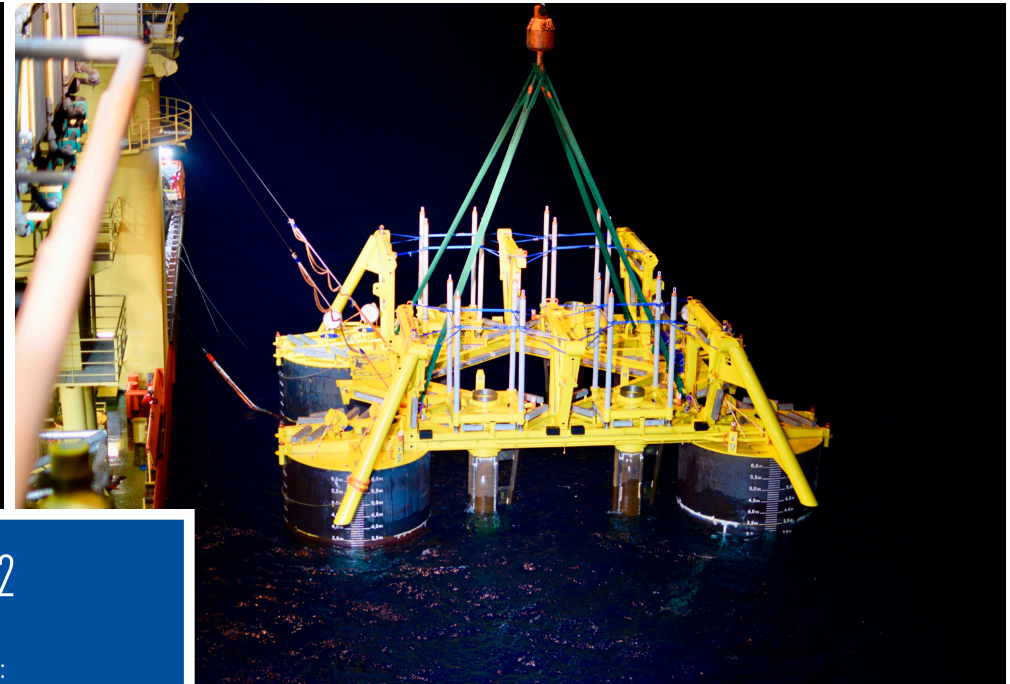
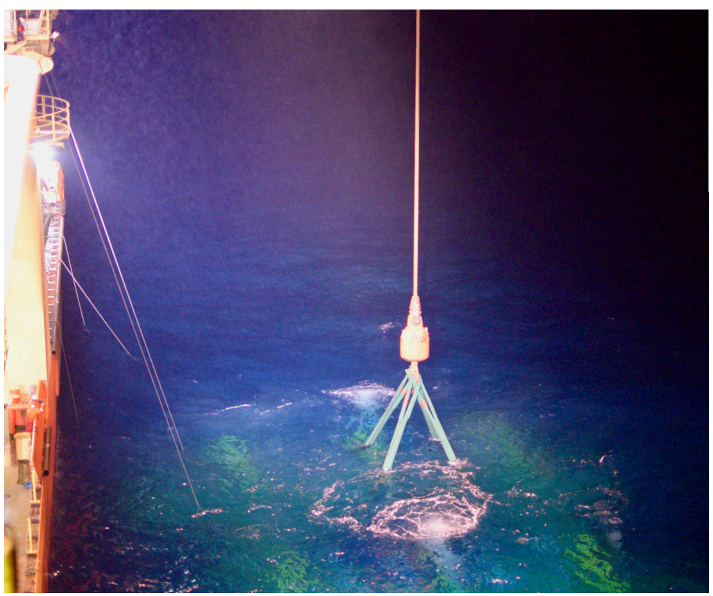




Project 2

Project Leader:
Ole Økland, SINTEF Ocean

Subsea: Safe – All-Year – Cost-efficient Subsea Operation

The scale of complex subsea field developments will probably increase. There will be a continuous need for cost improvements for field developments and the cost and ability of maintenance, repair and intervention of such fields.

Subsea installation and services have operational limitations due to environmental conditions such as waves, wind, currents and water depth. In areas with a harsh environment, there will be operational limitations in performing marine operations. For areas with water depth down to 3000 m, there will be limitations on weight and dimensions of modules and units. In addition there are challenges with vertical span dynamics. The water depth makes the operations time consuming and puts limitations on the payload capabilities. In addition the landing sequences may be complex due to sensitivity to current.

The objective of the project is to facilitate marine operations taking place in a commercial and cost-efficient manner and thereby contribute to positioning the Norwegian Maritime industry towards the market of such operations worldwide.

- Make operations safer and with required accuracy.
- Improve HSE by making the operations more robust vs. available weather window.
- Reduce total field development costs by more cost-efficient marine operations.
- Increase operational efficiency of subsea fields by all-year vessel operation.

The operational limitations of marine operations through a moonpool, or from the deck of an installation vessel are influenced by several factors. The specific limitations need to be assessed carefully based on vessel motion characteristics, the deck handling system (including personnel), and shape and size of the object to be installed. Accurate simulation tools are a vital key with respect to planning of operations as well as training for realistic operations with simulators and monitoring systems offering support during operations. In 2017, an important part of the work in this project has been related to assessment of hydrodynamic coefficients for various complex structures. This is a continuation of the work that was started in 2016, extending it from individual structure parts to complete structures. For project engineers, such coefficients are essential for reliable assessment of the forces in the lifting equipment and the structures. This is needed in order to determine the limiting sea state for operations. SINTEF Ocean have issued two scientific papers and a technical report that summarize the results from the 2017 study, and hydrodynamic load on complex structures is also the topic of one PhD and one postdoc in the subsea project.

A case study based on data from the subsea installation of an integrated template structure (ITS) with mass 285.7 t on the Johan Sverdrup field (depth 120m) was defined in 2016, and the first part of the study was carried out in 2017. The case study is being used to explore potential and limitation for different types of installation vessels and operations, and will serve as a basis for development and validation of new or enhanced simulation models, monitoring systems and implementation of enhanced functionality in simulator systems for training.

In 2017, a numerical model of the Johan Sverdrup ITS was developed based on the aforementioned hydrodynamic coefficients and was used to perform numerical simulations of the installation operation. For verification, the simulated vessel motions and hook loads during splash-zone crossing were compared with full-scale data collected by Ocean Installer during the actual operations. It was found that the results were consistent with the measured data, but that the dynamic loads were overestimated due to shielding from the vessel.
The numerical simulation methods were then used to study the effect of vessel size on the forces in the lifting equipment, showing that a large vessel size correlates with smaller forces. It was also shown that when the limiting sea state for the operation was calculated using numerical simulation methods, the limiting wave height was increased by 130% compared to the Simplified Method described in DNVGL-H103.

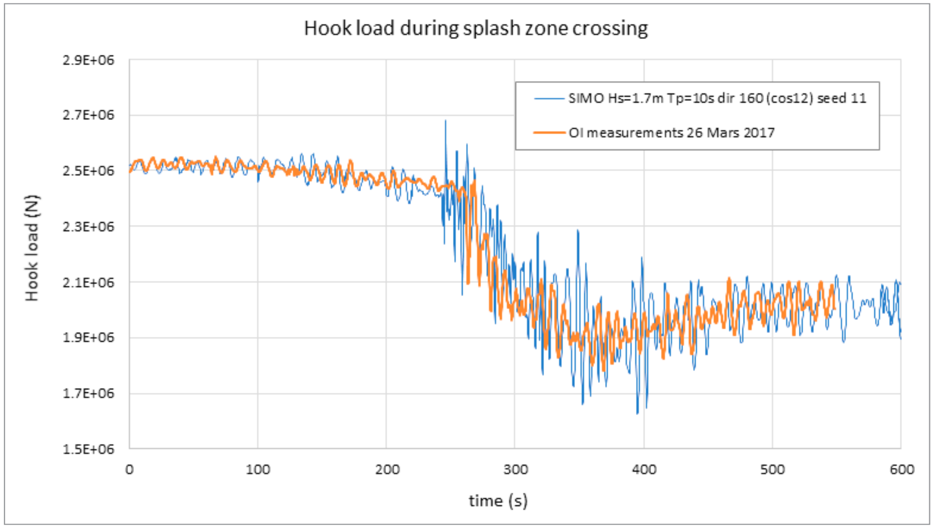


Figure 1. Simulated and measured hook load during a splash zone crossing. (Solaas, Jin and Sandvik: SFI-MOVE Case study. SINTEF report OC2017 F-172)

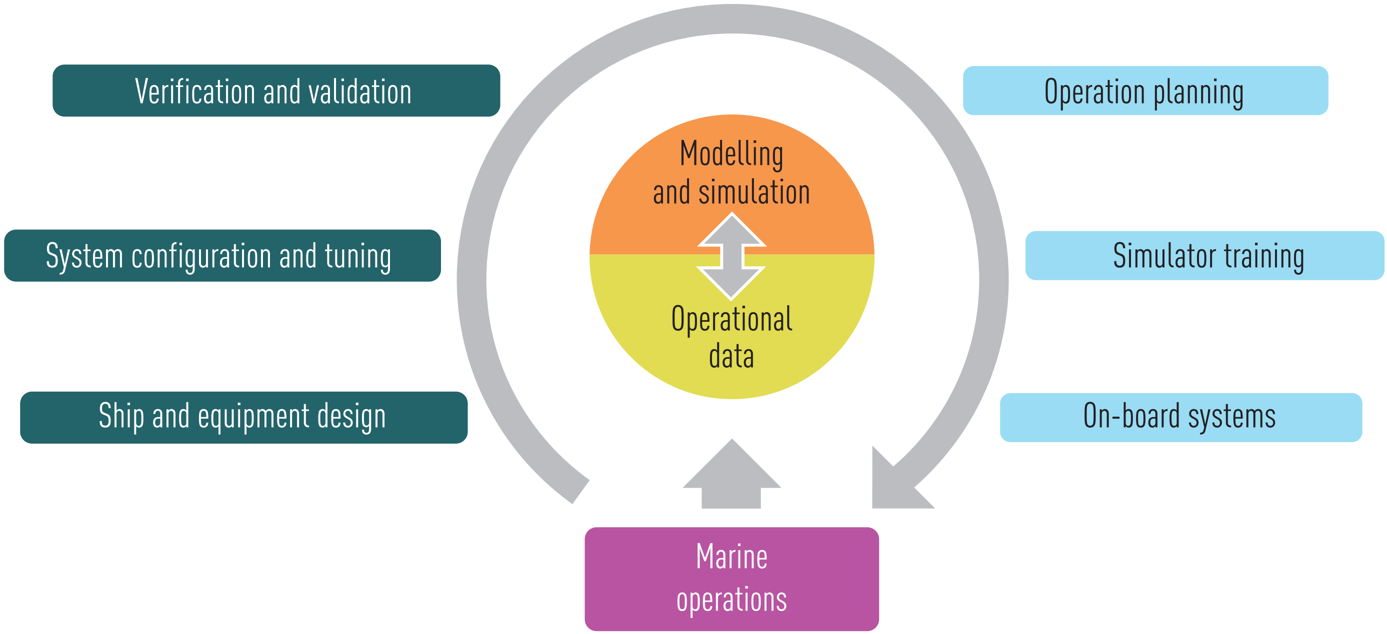
The further development of advanced offshore construction vessels (OCVs) will lead to increased operational performance which is not necessarily only dependent on vessel length and displacement. The question of what is a good offshore crane vessel is increasingly raised. To answer this question a holistic approach for the assessment of vessel performance is needed. A consistent set of criteria, considered as key performance indicators (KPIs) were established for crane vessels in close cooperation with the offshore industry. In 2017, a workshop was arranged with participants from the offshore sector to elicit experts' opinions collecting performance relevant indicators. Based on such interactions with the offshore experts, a methodology for vessel performance evaluation allowing task specific vessel selection has been developed.

Starting from 2018, this project will cease, but the work that was begun here will continue in the newly-established Project 6: On-board Decision Tool. In particular, the work on estimating hydrodynamic coefficients for complex subsea structures will be completed, and the results are planned for use in real-time simulations onboard vessels during operations as a basis for operational decision support. Furthermore, the Johan Sverdrup study showed a need for better methods for modelling shielding effects and tugger winch systems; these will be developed in 2018.

Project 3

Project Leader:
Lars T. Kyllingstad and
Henning Borgen, SINTEF Ocean

Simulation technology and virtual prototyping as a common approach from design to operation



The idea of the «Virtual Prototyping» sub-project was to explore the opportunities offered by simulation-based workflows and tools throughout the maritime value chain, from design to operation and, closing the loop, back to design again. The maritime industry is under constant pressure to deliver better solutions and more efficient operations at a lower price and in a shorter time span, and virtual prototyping methods promise great improvements over traditional workflows when it comes to achieving this.

The project has two primary goals:

- To establish common standards and formats for exchange and re-use of digital information and models in the maritime industry.
- To present methods and demonstrate how simulation and virtual prototyping can be used throughout the whole cycle from design to operation.

These are closely linked, as the former is a prerequisite to achieving the latter. Agreed-upon data formats would allow data collected in real operations to be more easily used by different people for a variety of purposes, while common modelling and simulation interfaces would allow exchange and re-use of mathematical models between organisations and throughout the maritime value chain. There are several obstacles to achieving this, and perhaps the most important one is the wide diversity of incompatible, proprietary and often in-house software systems in use today.

The project has focused its efforts around two standard interfaces:

- The Functional Mock-up Interface (FMI), a tool independent standard for model exchange and co-simulation. In principle, the FMI allows a numerical model created with one software tool to be imported and used by a different tool, given that both tools support this standard. FMI has already become something of an industry standard in the automotive industry, and the list of simulation tools that support it is large and growing rapidly.
- The Data Distribution Service for real-time systems (DDS), an OMG middleware standard that enables scalable, reliable, high-performance, and in particular interoperable data exchange between different systems. There exist several implementations of this standard, both commercial and free, and it is used in areas as diverse as air traffic control, financial trading, military war games and building automation systems.

One particularly interesting aspect of DDS is that it enables data centric, rather than system centric, information exchange. It uses a publish-subscribe communication pattern in which the systems that consume data (subscribers) only need to specify which data they are interested in and not where the data should be obtained from, thus de-coupling them from the systems that produce it (publishers).
In the context of maritime virtual prototyping, the use of DDS for data exchange on vessels could significantly reduce the effort needed to develop, test and install on-board control and information systems. Firstly, since the data consumer is less tightly coupled to the data source, using a simulated vessel in lieu of the real vessel in a testing situation becomes much more straightforward, enabling more thorough testing within a given time frame and budget.

Secondly, assuming that the instruments and sensors on board the vessel publish information using agreed-upon data structures, on-board systems could be less tailored to each vessel, and the potential for vessel-specific installation and tuning errors would be significantly reduced.

In 2017, with these goals in mind, the project has carried out the following work:

- Expanded the FMI support in simulation tools used in the marine operations domain, in particular SIMO, which is the primary numerical tool of SFI MOVE, and Coral, an open-source co-simulation software.
- Developed an experimental FMI-to-DDS bridge module which can be used to connect an FMI-based co-simulation to a DDS-based on-board system. The idea is to make it easy to replace the real ship with a «virtual ship» in a development and testing situation.

Starting from 2018 this project will cease, but the work that was begun here will continue in the newly-established Project 6: On-board Decision Tool. The new project will develop an on-board decision support system for offshore crane lifting operations, coupling simulations of the vessel, crane and load dynamics to a real-time data stream from onboard sensors in order to predict the response of the vessel and the behaviour of the load.

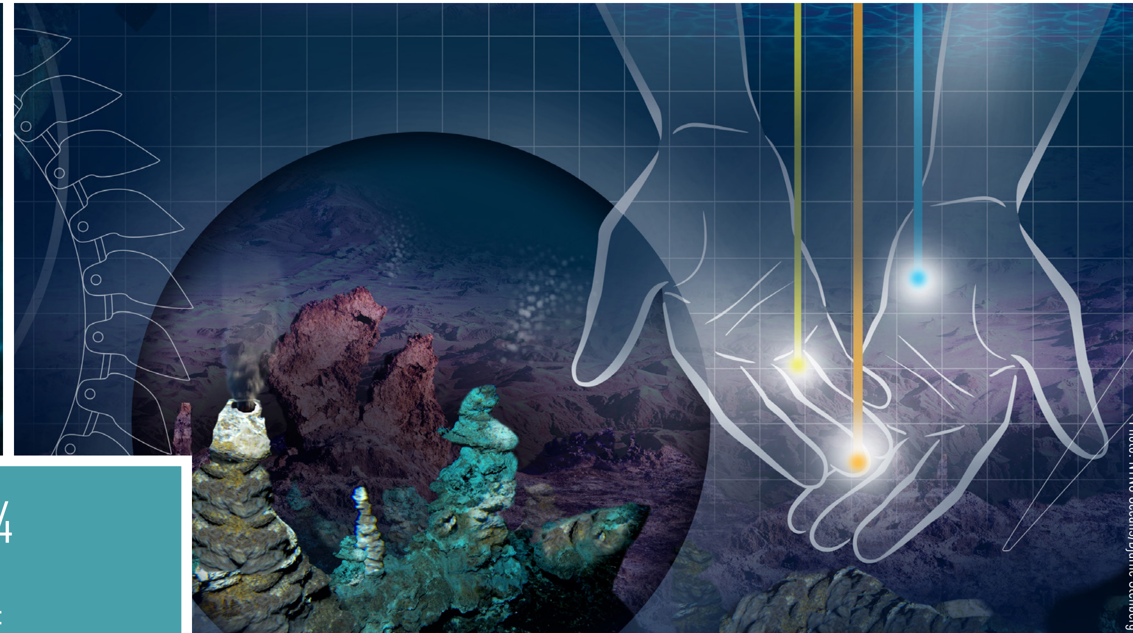
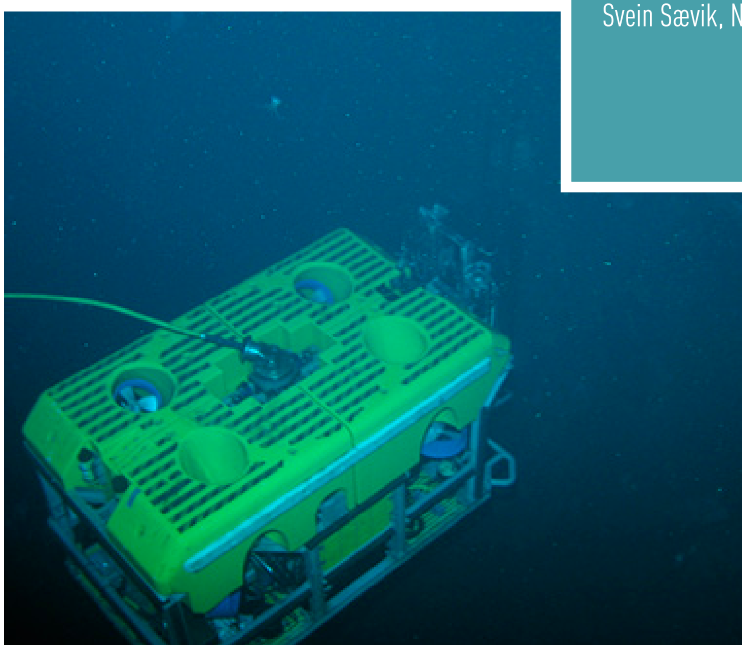


Photo: NTNU Oceans/Bjarne Stenberg

Project 4

Project Leader:
Svein Sævik, NTNU



Seabed Mining:

Exploration of Technologies to Develop Seabed Mining as a New Business Area

The interest for subsea mining is growing. Norway controls one of the world's largest sea areas - six times the land area of Norway, including the northern expanse of the Mid-Atlantic Ridge. In Norwegian waters alone, NTNU study estimate low value 75 bn USD. No upper limit. The Marmine NFR project (https://www.forskningsradet.no/prosjektbanken/#!/project/247626/no) started with a research cruise to the Arctic Mid-Ocean Ridge (AMOR) in 2016, covering the extended Norwegian Continental Shelf. NTNU and NIVA, together with several research partners, surveyed and sampled potential mineral deposits on the ridge. AUVs and ROVs were used for surveying selected target areas. Survey data were collected using different types of imaging equipment to provide means to define the prospective sites. The mission included water depths down to 3000 m. Selected sites were studied through sampling of rocks and drill cores from the sea floor and inside the upper part of the sea floor. This sample material will be used for characterization of the ores.

Parallel to this, NTNU Oceans, Pilot Deep sea mining is an ongoing project being part of NTNU Oceans, which is one out of four strategic research areas at NTNU. This program coordinates all activities related to sustainable Ocean Space utilization (https://www.ntnu.edu/oceans). With respect to Ocean Mining the current activities include a wide range of related topics: Autonomous exploration, detection of seafloor minerals based on spectral signatures, energy supply, environmental aspects of deep sea mining, ethics and social responsibility, exploration – geophysics, history of subsea mining – legal aspects, platform development, resource assessment, resource geology and vertical transportation.

With respect to SFI MOVE, the marine operation aspects of ocean mining including the structural behaviour of the riser system needed to transport the deposit from the seabed to the vessel is focused on. The material transport may be provided by pumping water and rock particles (slurry flow) possibly combined with compressed air through the riser. The structural behaviour of the riser system when exposed to both external current and internal flow at large water depths is identified as a critical topic. Therefore, two PostDocs, Niranjan Reddy Challabotla and Mats Jørgen Thorsen have been allocated in SFI MOVE to work on these issues. The objective includes development of models that enable studying coupled dynamics phenomena related to both two phase (water and rock) and three phase flows (water, rock and air). The overall objective of the work is to provide a fully dynamic model that can handle both steady state and transient dynamics of such systems. The concept is illustrated in Figure 1 and its performance as compared to the state of the art is illustrated in red in Table 1 where it is noted that the state of the art of today only includes Methods 1–3.

During 2017 the development of the 1D dynamic model for vertical transportation in ocean mining has been continued with respect to:

- Development of 1D dynamic vertical transport model based on the in-house multi-phase flow code SLUGGIT
- Completing the code development for slurry transport and air lift techniques
- Simulations performed for gas-liquid flow in 20m vertical riser, which will be validated with the ongoing experiments conducted by a master's student
- Participating in World NAOE Forum 2017 and EU Bluemining project meetings

Also, the work on coupling the above flow model has continued with respect to:

- Implementation of VIV hydrodynamic load model in RIFLEX
- Development of a framework for coupled RIFLEX-SLUGGIT simulation (riser dynamics and internal multi-phase flow)

The following papers have been published or are under review as a result of the work in 2017:

- M.J. Thorsen, and S. Sævik. (2017) Vortex-induced vibrations of a vertical riser with time-varying tension. Procedia Engineering 199.
- M.J Thorsen, and S. Sævik. (2017) Simulating Riser VIV in Current and Waves Using an Empirical Time Domain Model. ASME 2017 36th International Conference on Ocean, Offshore and Arctic Engineering.
- M.J Thorsen, and S. Sævik. (2018) An Analytical Model of the Effect of Internal Density Waves in Risers Subjected to Vortex Shedding. ISOPE Conference (under consideration for IJOPE journal).
- M.J. Thorsen, S. Sævik and O.J. Nydal. (2018) Coupled dynamic analysis of pipes subjected to vortex-induced vibrations and internal two-phase flow. To be submitted for journal publication.

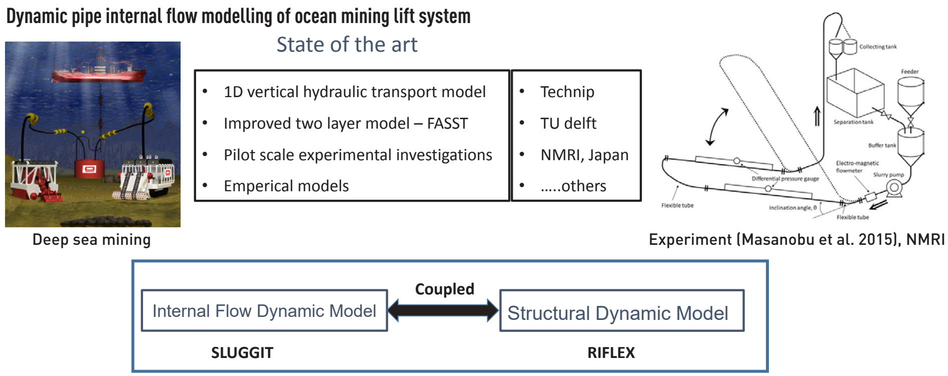


Figure 1: The coupled dynamic model concept

	Flow model	Structural model
Method 1	Steady state	Static
Method 2	Steady state	Dynamic
Method 3	Transient	Static
Method 4	Transient	Dynamic

Table 1: Illustration of the research objective (red) as compared to the state of the art.

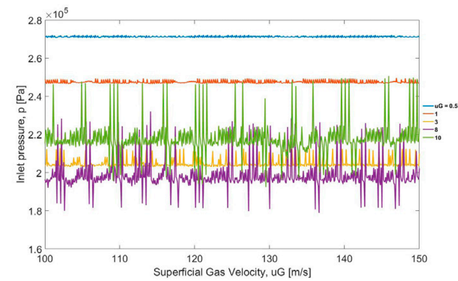


Figure 2: Inlet pressure variation for different gas flow rates in air lift technique

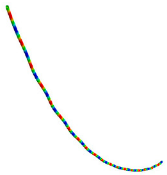


Figure 3: Snap shot of mass distribution in riser due to internal flow

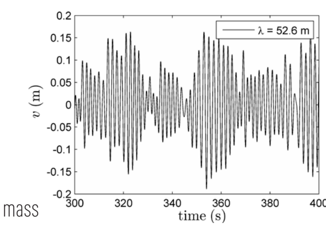
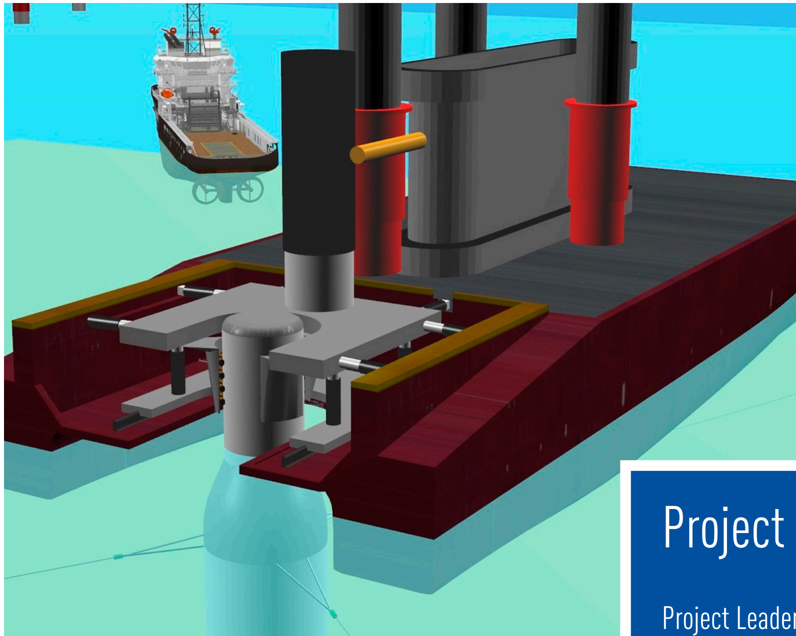
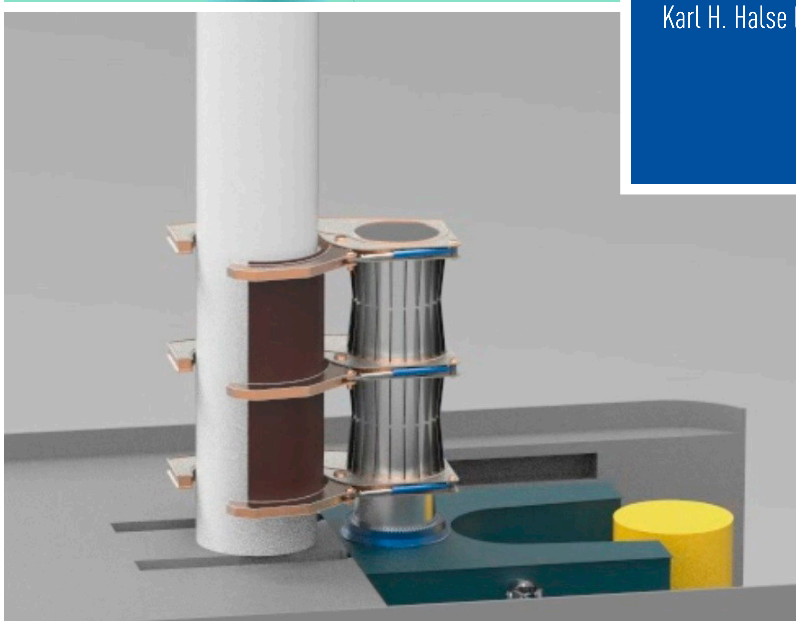


Figure 4: Time series of coupled VIV and flow induced motion



Project 5

Project Leader:
Karl H. Halse (NTNU Ålesund)



OW: Installation of Offshore Wind Power Systems

The installation costs of a typical offshore wind power plant are a substantial part of the overall costs for the project (up to approx. 30 % of the total development costs). The Dogger Bank Wind Park Project is planning for several hundred offshore wind turbines to be installed in rather shallow water. Today, fixed Offshore Wind Turbines (OWT) are installed with the use of high lift cranes from jack-up platforms (or jack-up ships). This is a costly and time-consuming way of installing the turbines. During the summer of 2017, Statoil installed the world's first floating wind power park, known as Hywind Scotland. The wind park consists of five floating wind turbines of 6 MW each and is estimated to cost approx. NOK 2 billion. The installation cost of Hywind Scotland was greatly reduced compared to the single Hywind Demo unit installed in 2009. However, the installation costs were still substantial, giving motivation to find a more cost-efficient way of installing floating offshore wind parks.

A fundamental idea for much of the work in SFI MOVE is to be able to extend the concept of simulating marine operations to be more than a training tool. We want to use the simulator also as a demonstration and design tool. This requires models that can be simulated in real time, which in turn means we have to simplify the dynamic models used.

Installation of a floating Offshore Wind Turbine from a catamaran

During 2017, we have continued to study the motion response of the proposed catamaran-shaped installation vessel. We have used the physical modelling capabilities in AGX to model the motion of the SPAR buoy, the catamaran and the OWT to be mounted onto the SPAR buoy. The AGX vessel motion prediction is compared to state-of-the-art response prediction tools as WAMIT/VERES, to try to gain confidence in the simulated catamaran motions.

Furthermore, the coupled hydrodynamic analysis of the catamaran and the SPAR is studied in SIMO to understand the hydrodynamic interaction effects between the SPAR buoy and the catamaran vessel. The feasibility of the catamaran vessel for installing floating wind turbines was demonstrated by a numerical study using SIMO-RIFLEX, with focus on the mating phase when a 6MW wind turbine assembly is being positioned on top of a SPAR foundation. The numerical model includes both the first and second order wave loads on the catamaran and SPAR and the wind loads on the wind turbine assembly, the hydrodynamic interaction between the catamaran and the SPAR, the mechanical coupling between them through sliding grippers, and the dynamic positioning of the catamaran and the mooring system of the SPAR. Responses of the motions of the catamaran-SPAR system, and the contact forces between them in representative sea states were estimated and compared with the allowable limits.

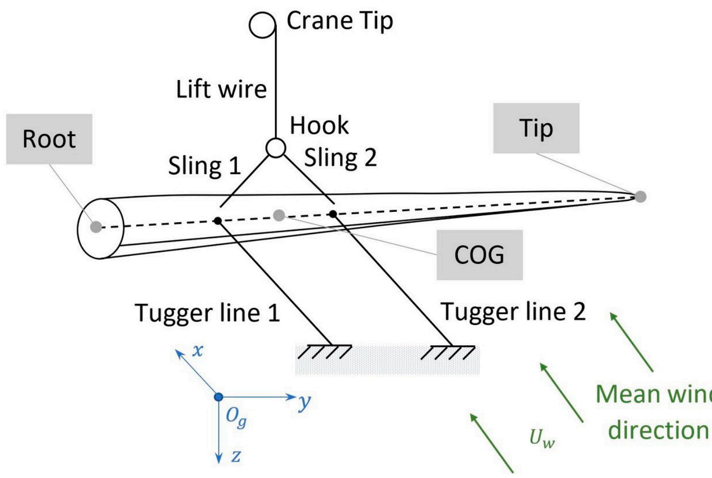
Finally, the lifting mechanism to transfer the OWT tower from the catamaran deck to the floating SPAR is redesigned. The hydraulic system and the control model to minimise the relative motion between the lifting mechanism and the SPAR foundation is under development.

Installation of fixed Offshore Wind Turbines from a jack-up vessel

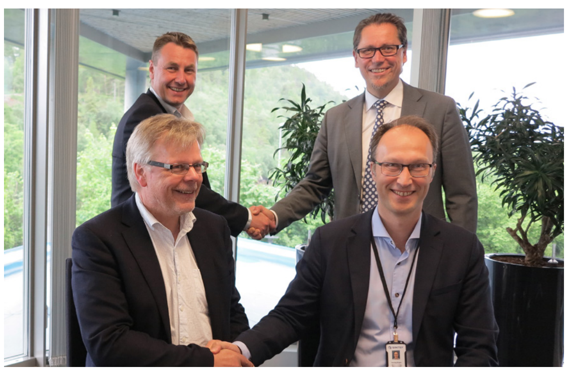
A modularized simulation toolbox for the purpose of control design for a single blade installation by crane operation was developed in MATLAB/Simulink. Based on the developed toolbox, an active tugger line tension control is proposed and demonstrated to be very effective to reduce the relative motion between the blade root and the hub during the final mating phase of the installation. Additionally, a nonlinear model predictive controller is designed to reduce the transient dynamic tension during the lifting operation.

Global response analysis and impact loads on wind turbine blades during installation

A numerical code, Aero, was developed to calculate the wind loads on a single blade in a turbulent wind field during installation and coupled to SIMO-RIFLEX for global dynamic response analysis of the blade using a jack-up vessel for installation. It is observed from the numerical study that,



the wave loads on the jack-up vessel legs induce large crane tip motions due to the vibration of the legs and the crane during installation, while the wind loads on the blade induced large pendulum motions of the blade. The results of the blade motions were used to assess the sea-state operational limits considering the response-based criteria, which were established explicitly by numerical simulations of blade damages due to contact or impact of the blade with the surrounding structures during the lifting operation or the hub during the mating operation. A finite element structural model of a single blade was established in ABAQUS taking into consideration the detailed composite layup of the blade cross-section. An impact analysis of the blade cross-section with the tower was performed for a range of impact speeds. Different failure modes of the composite materials were simulated. A mapping between the blade impact velocity and the blade damage was then established and used together with the global response analysis to assess the operational limits for blade installation.



Research cooperation

An open simulation platform

Today, simulations are widely used in all stages in the life cycle of a vessel. However, the potential of simulations is not fully utilized as the initial cost of establishing simulation models is considerable, and re-use of models is limited. Based on a standard developed by the automotive industry we aim to establish a standard also in the maritime industry, enabling re-use of models and collaborative system simulations.

Partners in SFI MOVE, DNV GL, Rolls Royce Marine, SINTEF Ocean and NTNU, have agreed to act on this challenge together. We propose bringing together key industry stakeholders to define a standard enabling exchange of simulation models – reducing cost and complexity related to simulations. Through a 2-year joint industry project we want to develop an open source simulation environment to facilitate model sharing and co-simulation for the maritime industry. The new standard will be based on well-established standards from the automotive industry.

The output of the project will be a foundation for collaborative sharing of simulation models and an open industry platform for creating digital twins of products, systems and complete vessels. This can be used to verify system integration, aid system design, and plan and optimize vessel operation in a virtual environment. As a project participant, you will have the opportunity to directly influence the industry standard, participate in use case pilots, have early access to the supporting technology and get support for technology usage.

Ocean School of innovation

The group has in cooperation with NTNU-TTO established Ocean School of Innovation. This is a joint initiative between several centers to increase awareness and competence on innovation among PhDs and researchers.

Objectives of the School of Innovation:

1. Create a culture for innovation
2. Strengthen the awareness and competence on innovation
3. Contribute to increased commercialization of research results

Ocean Scool of Innovation provides:

Courses and Training

- Entrepreneurship
- Innovation in start-ups and large companies
- IPR and Asset Management
- Design Thinking

Culture for Innovation

- Innovation Lunches
- Teambuilding and Networking
- Pitching
- Tech Transfer Speed-dating
- Funding Opportunities

Activities 2017

Innovation lunches

- Behind the scenes of Memfoact (22.02.2017) Cancelled

Seminars and courses

- TrollLabs «Publish or perish – Demo or die» (17.02.2017)
- Technoport «Intrapeneurship and Business Model Canvas» (07.03.17)
- Improved presentation skills «Pecha Kucha workshop» (04.03.2017)
- Intellectual property management «Transformation of IP in the university arena» (28.09.2017)
- Lean Startup «Playing Lean Workshop» (07.12.2017)

Other activities

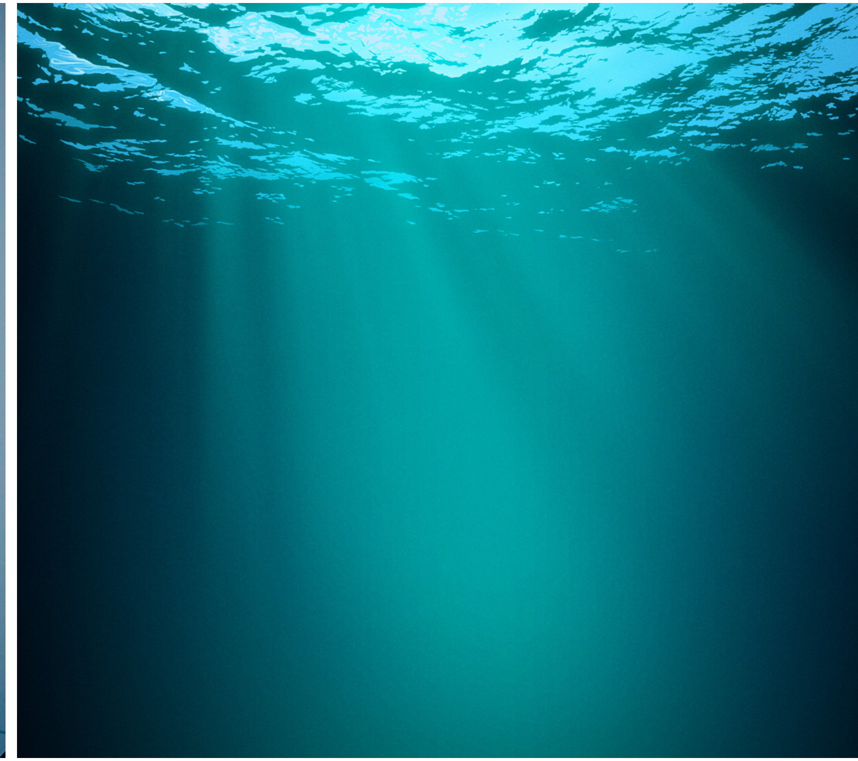
- Pecha Kucha training for Ocean week presenters
- Pecha Kucha pitching event at Ocean week

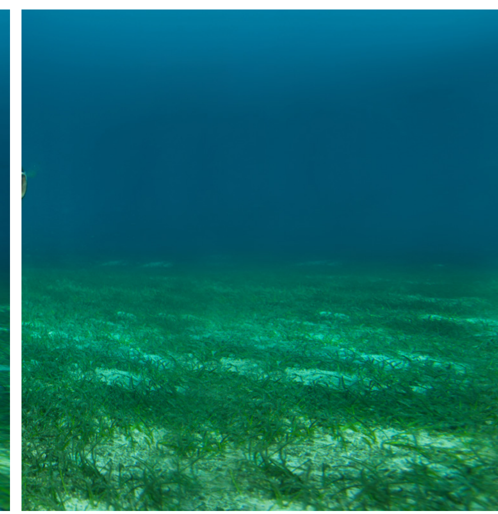
International cooperation

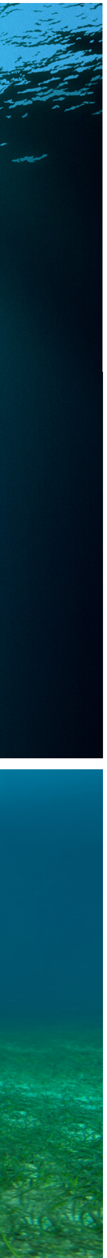
The MOVE Centre has a strategic cooperation with the University of Sao Paulo (USP) in Brazil. The key person in contact is professor Kazuo Nishimoto. USP is combining marine research and nautical operations and has a similar approach as we have defined in SFI MOVE. A cooperation agreement is signed.

The MOVE Centre has also a strategic cooperation with the University College London (UCL).

NTNU Ålesund has been cooperated with Massachusetts Institute of Technology (MIT) within innovation and entrepreneurship. Professor Bill Aulet at MIT offered a one week course in entrepreneurship June 2017.





Recruitment

Due to late start of the SFI MOVE we had a minor delay in hiring PhD students from the start. We are very pleased with the number and quality of applications.

PhD candidates and Postdocs					
PhD candidates with funding from SFI MOVE					
Name	**Start**	**Planned exam**	**Project**	**Nationality**	**Gender M/F**
Martin Friedwart Gutsch	2015	2019	Subsea Safe All Year	German	M
Fredrik Mentzoni	2015	2018	Subsea Safe All Year	Norwegian	M
Zhengru Ren	2016	2018	Offshore Wind Innovative Installation	Chinese	M
Amrit Shankar Verma	2016	2019	Offshore Wind Innovative Installation	Indian	M
Robert Skulstad	2016	2019	Virtual Prototyping	Norwegian	M
Maël Moreau	2017	2020	Subsea Safe All Year	French	M
Jiafeng Xu	2015	2018	Subsea Safe All Year	Chinese	M
PhD candidates with funding from other sources					
Tor Huse Knudsen	2014	2018	Mining	Norwegian	M
Svenn Are T. Værnø	2014	2017	Virtual Prototyping	Norwegian	M
Senthuran Ravinthrakumar	2016	2019	Subsea Safe All Year	Norwegian	M
Øyvind Rabliås	2017	2021	Subsea Safe All Year	Norwegian	M
Tore Relling	2017	2020	Virtual Prototyping	Norwegian	M
Rami Zghyer	2017	2021	Virtual Prototyping	Jordanian	M
Postdocs with funding from SFI MOVE					
Mia Abrahamsen Prsic	2016	2018	Subsea Safe All Year	Croatian	F
Zhiyu Jiang	2016	2018	Offshore Wind Innovative Inst.	Chinese	M
Mats Jørgen Thorsen	2016	2018	Mining	Norwegian	M
Niranjan Reddy Challabatla	2016	2018	Mining	Indian	M

PHD-STUDENT

Department of Marine Technology • Faculty of Engineering

Martin Gutsch

Photo: Thor Nielsen

Title

Performance Indicators for vessels performing challenging marine operations.

Research topics

The ongoing exploration of the maritime environment and the constant effort to use the sea as a source of energy in the context of increasing financial constraints leads to increasing global demands for more economical and weather independent services within marine operations. Although ships and on-board equipment are designed to operate in harsh environmental conditions, the current practice is often to terminate operations when a rigid and often conservative weather limitation is reached, often specified in terms of the significant wave height as the exclusive criterion. Since the offshore industry is aiming for all-year-round safe operations, a strong interest among ship designers, owners and operators arises to establish and use vessel and task-specific criteria aiming at the full vessel-specific exploitation of operational performance.

The main objective of the PhD work is to address the question of what makes an offshore working vessel perform better, especially in harsh environmental conditions. The identification of rational performance criteria for vessels fulfilling selected operational tasks shall provide knowledge for a better understanding of factors contributing to a successfully completed offshore work task and shall deliver tools to estimate ship-specific operational limitations.

Industrial goals

The use of rational performance criteria shall provide a methodology and tools to evaluate operational performance by the use of vessel- and task-specific limitations beyond a general HS-limit. This addresses a primary concern of the offshore industry to increase operability and approach the objective of safe all-year operations. The work shall provide strategies for the application of performance measures in order to support the vessel design process, the assessment of vessel performance in operations, and the selection of the suitable vessel for a specific task.

Scientific questions

- What is a good offshore vessel and why are some vessels performing better than others?
- What are vessel-specific factors contributing to operational performance?
- What are performance indices to measure and quantify vessel-specific operational potential?
- How to validate newly-established performance indices?

Innovations

The knowledge of operational performance criteria shall:

- give guidance for vessel design with the goal of increased operability, cost-efficiency, and safety.
- provide knowledge for the assessment of vessel design for a specific operational task and estimated environmental condition with the aim to select the most suitable vessel for a defined operational task
- provide tools to identify task-specific weaknesses for a given ship design and/or the planning of an operation and give guidance for improvements
- provide information for further development of on-board support systems

Cooperating companies

Ocean Installer

Statoil

Supervisor: Sverre Steen

Co-supervisors: Florian Sprenger, Trygve Kristiansen

PHD-STUDENT

Department of Marine Technology • Faculty of Engineering

Fredrik Mentzoni

Photo: Thor Nielsen

Title

Hydrodynamic loads on complex structures in the wave zone.

Research topics

The purpose of the PhD work is to provide enhanced knowledge about hydrodynamic loads on complex structures during deployment. This includes performing new benchmark experiments for hydrodynamic loads in the wave zone. The end goal is to develop rational methods for load estimates on complex structures.

Industrial goals

Rational methods to calculate hydrodynamic loads on complex structures need to be developed to ensure proper load estimates for marine operations involving, among others, the replacement of complex modules for subsea installations. Experience show that planning of marine operations is of high importance. Load predictions in terms of rational load models are necessary in this respect. Rational methods have been developed for simpler geometries, but there still exists knowledge gaps on several fundamental issues as well as large uncertainties in the hydrodynamic load estimates for more complex structures.

The present research will focus on hydrodynamic loads on 2D and 3D structures in the wave zone – as the structure goes into water – with regards to off-the-side (crane) operations. Moon pool operations and loads as the structure is further submerged and lowered to its seabed destination may also be relevant.

Scientific questions

- Is it possible to accurately estimate hydrodynamic loads on complex structures?
- Which effects dominate the load response at different stages during deployment?
- How can rational models be simple and fast to use, and at the same time take into account the complexity of subsea structures?
- How can the current recommended practices be improved to increase accuracy of load predictions for complex structures?

Innovations

Increased knowledge on hydrodynamic loads on complex structures in the wave zone can contribute to innovations and new solutions for offshore marine operations. This includes increased predictions of hydrodynamic loads that can be used for development of software, calculation methods, operational window predictions and new solutions for lowering of structures through the wave zone. In addition to potentially increasing the operability and reducing cost, research findings may also contribute to increased confidence in training and planing of marine operations.

Cooperating company

DNV GL

Supervisor: Trygve Kristiansen
Co-supervisor: Odd M. Faltinsen

Title

Control and Online Decision Support of Crane Operations for Fixed and Floating Offshore Wind Turbines.

Research topics

- Build control plant models for marine lifting operation.
- Design controllers to precisely locate the payloads (lumped-mass, tower, and blade) and verify it through experiments.
- Consider fixed-to-floating, floating-to-fixed, and floating-to-floating installation operations, as well as an integration with DP system.

Industrial goal

- Design real-time robust controllers for the mating and positioning operations during wind turbine installation.
- Improve the weather limits during lifting and mating operations.

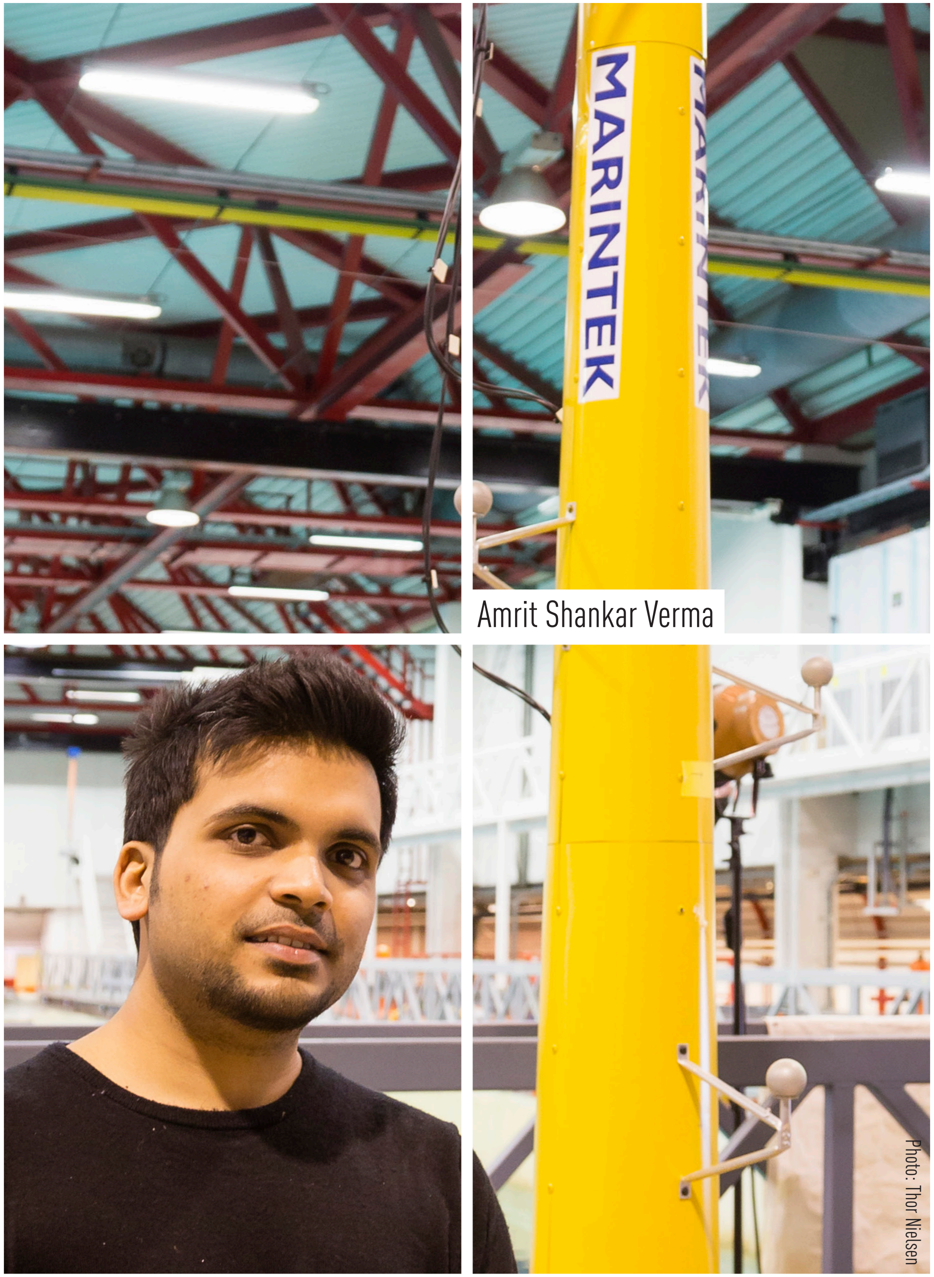
Scientific questions

- Influence of wave-induced motion to the crane operation; Underactuated system; High lifting; Robust control; Model-free control.

Innovations

- Attempt to study vessel-based installations, not commonly jackup-based.

Supervisor: Roger Skjetne (IMT, NTNU)
Co-Supervisors: Zhen Gao (IMT, NTNU)



Amrit Shankar Verma

Photo: Thor Nielsen

Title

Development of explicit response-based criteria for operability assessment for installation of offshore wind turbines using floating vessels.

Research topics

In view of the movement of offshore wind industry into deeper waters and the limitation of jack-up vessels, floating crane vessels are now being developed and used for installation of bottom-fixed wind turbines and also floating wind turbines (for example spar wind turbines). However, the big challenge is the motions of floating crane vessels, which may lead to contact/impact between the objects and therefore damages in the critical components (blades, nacelle or pre-assembled rotor-nacelle-tower) in particular in the lift-off and mating operations. In order to obtain an accurate estimate of the operability to reduce the cost for such operations, it is crucial to develop response-based criteria by explicitly assessing the damages in the wind turbine components in case of contact/impact. The purpose of this study is to develop the numerical methods for response and damage assessment of critical wind turbine components during installation and to derive the operational limits in terms of sea state parameters (Hs and Tp) for operability assessment. Case studies for installation of individual blades and integrated rotor-nacelle assembly onto bottom-fixed foundations and floating foundations using floating installation vessels will be considered. Active winch control to reduce or avoid the contact/impact during lifting operations will also be considered.

Industrial goals

- To reduce costs in the installation of OWTs by using floating installation vessels
- To develop explicit motion and structural response-based criteria for floating installation vessels

Scientific questions

- What are the criteria for operability assessment in terms of allowable vessel motions or allowable structural responses (maximum stress or allowable damage) of the critical components (blades, rotor-nacelle assembly) during installation?

Innovations

- A new way to determine the operational limits for floating installation vessels using response-based criteria

Cooperating company

Statoil
DNV-GL

Supervisor: Zhen Gao
Co-supervisors: Torgeir Moan, Karl Henning Halse, Nils Petter Vedvik

PHD-STUDENT

Department of Ocean Operations and Civil Engineering • Faculty of Engineering

Title

Data based ship motion prediction in offshore operations

Research topics

- Ship motion prediction
- Time series prediction models and input selection

Industrial goal

- Decision support/controller feedback for autonomous vessels
- Fault detection

Scientific questions

- How can data from sensors on ships be combine to provide long-term prediction of ship motion?

Innovations

- Methods for long-term ship motion prediction leading to improved guidance and navigation of vessels and increased safety at sea

Cooperating company

OSC AS

Supervisor: Houxiang Zhang (IHB, NTNU)
Co-Supervisor: Thor I. Fossen (ITK, NTNU)
and Bjørnar Vik (Rolls-Royce)

Title

Hydrodynamic study of roll motion of offshore vessels in operation.

Research topics

The roll damping is crucial for the vessel performance. Since the damping is dominated by viscous loads due to flow separation from bilge keels or other appendages, state-of-the art industry codes based on potential flow theory cannot predict this, and rely on empirical methods. Empirical methods have been developed for conventional type of hulls with bilge keels for several decades, and good empirical methods (e.g. Ikeda 1976 to 1978) exist. 2D roll damping coefficients for mid-ship sections are found (in still water), and applied in a strip-wise manner along the ship. However, for other variations of the hull form than the conventional, Ikeda's formulas are not applicable. This applies particularly to novel designs of vessels used in offshore operations that deviate strongly from conventional hull.

Further, how to apply the formulas (roll damping coefficients) in a stochastic sea is not well-established, even for conventional hulls.

A main research task will be to design a method to predict roll damping (coefficients) for non-standard hull types, while another will be to investigate the applicability of the (still water) hydrodynamic coefficients when the ship is freely floating in waves. A 2D type of study will be conducted, including experiments and numerical work.

Industrial goals

- Provide a better understanding of the physics, and reliable estimations of the roll motion of offshore ships in operation
- Provide a better prediction of the roll response to irregular waves in view of defining an appropriate weather window

Scientific questions

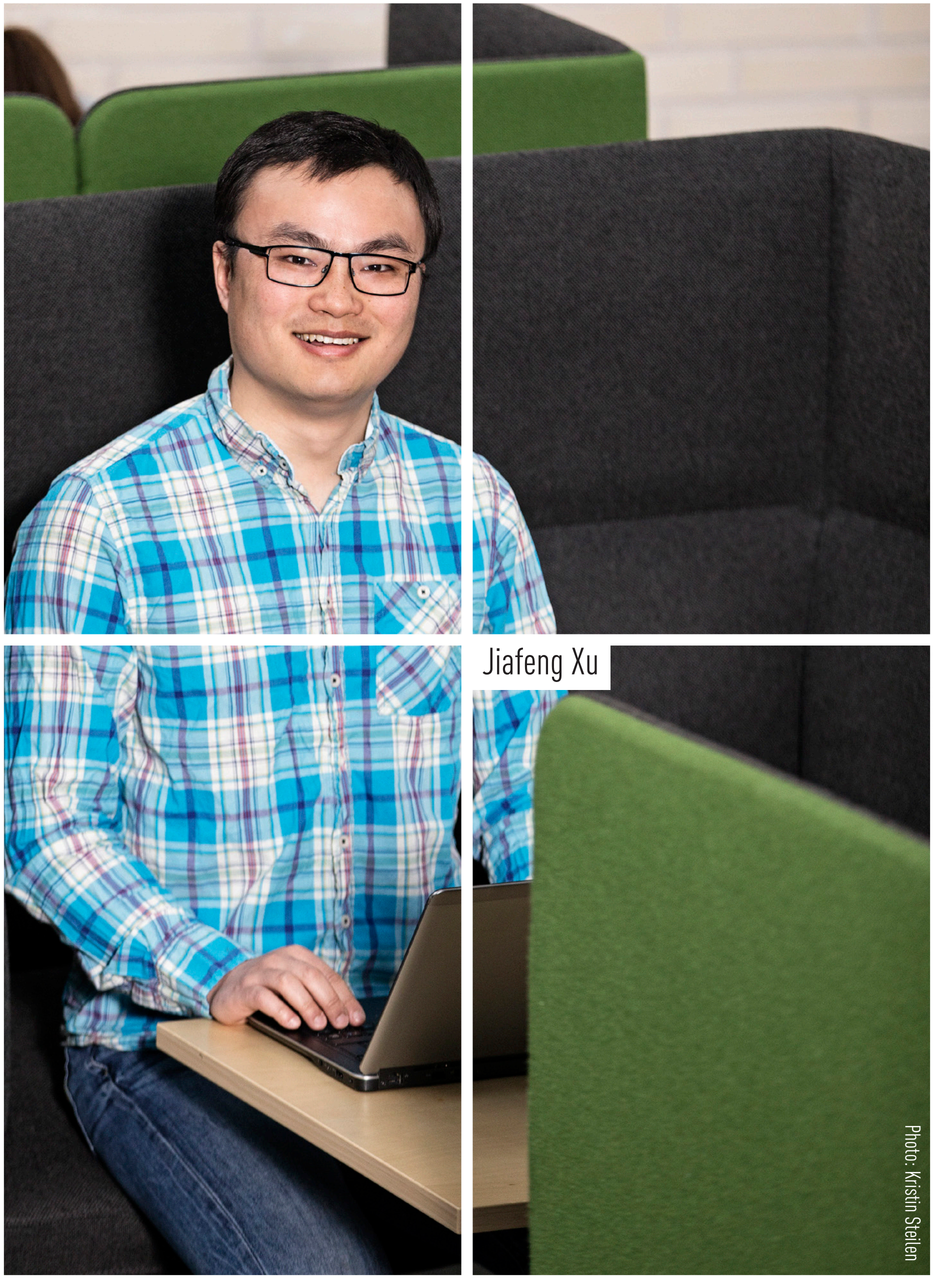
- How to predict the roll damping accurately for unconventional hulls
- How to extend the equation of motion in still water to irregular sea states

Innovations

Propose a method of estimating the hydrodynamic coefficients that is adapted for the study of the roll motion of offshore vessels.

Supervisor: Trygve Kristiansen
Co-Supervisor: Babak Ommani

Department of Ocean Operations and Civil Engineering • Faculty of Engineering



Jiafeng Xu

Photo: Kristin Steilen

Title

Real-time Simulation of Marine Operations.

Research topics

My research aims at developing a computer program environment and proper algorithms that can simulation marine operation in real-time with good reliability and flexibility. The focus will be on the result accuracy and calculation speed. Such simulation can serve as a powerful tool for both personnel training and product development.

Industrial goals

Ongoing projects include development of multibody dynamics simulation environment and development of real-time hydro-dynamic simulation with mesh or meshless method. A more integrated simulation framework with higher interaction level between different systems can better predict different kinds of marine operation scenarios. With better knowledge from the simulation, operators can make faster and more rational decisions in real operations and engineers can adjust the products more efficiently with lower cost.

Scientific questions

- How to define a generic and robust simulation framework?
- How to implement modular concept into simulation?
- How to democratize simulation methods to the industry?

Innovations

Traditional methods need to be modified and adapted to the real-time world. Isolated simulation perspectives need to be integrated for a higher interaction level.

Cooperating company

Offshore Simulation Center (OSC)

Supervisor: Karl Henning Halse
Co-supervisor: Eilif Pederson

Mia Abrahamsen Prsic

Photo: Thor Nielsen

Title

Hydrodynamic loads on submerged complex structures under the influence of waves and currents.

Research topics

The main goal of the postdoctoral research is to provide deeper understanding of the hydrodynamic forces exerted on the subsea modules during the structures' deployment. Due to the complexity of the structures, it is generally too demanding to model the realistic subsea modules, either experimentally or numerically. However, it is possible to represent the dominant parts of the structures by selected generalised elements, such as porous plates and cylindrical structures representing simplified module cross-sections.

Such elements are systematically examined, in different combinations, increasing the complexity, to explore the governing physical effects relevant for the hydrodynamic loads. Modelling is performed for the generalised structures subjected to the forced oscillations, representing the waves exerted on the fully submerged subsea modules.

The experimental results offer a systematic overview over the hydrodynamic coefficients for the various basic elements and their combinations, and are performed for a broad span of sea states that a real subsea module can experience.

CFD simulations complement the experiments by providing an insight in the details of the flow around the structures and the interactions in the flow field. Numerically simplified CFD models allow quick and efficient calculations of more complex structure combinations, and can thus be recommended for the practical, industrial use. They are compared to the detailed, three-dimensional turbulence CFD models to understand the limitations and advantages of various simplified approaches.

Industrial goals

Increasingly complex marine operations require safe and robust planning and all-year accessibility, relying on accurate calculations of the hydrodynamic loads. The goal of our project is to contribute to the current rational methods and recommended practice by systematic understanding of the hydrodynamic forces on various elements and flow interactions in the structures, providing guidelines for reliable use of the experimental and the numerical procedures.

Scientific questions

- What types of generalised, basic structures can be used to represent the dominant parts of the large, complex, three-dimensional subsea modules? How accurate are such representations?
- What are the main physical parameters and effects influencing the hydrodynamic forces on such basic structures and their combinations?
- When can the specific basic elements be observed as the individual contributors to the hydrodynamic forces of the complex modules, and when are the interactions between the various structural elements important?
- How precise and how applicable are various types of CFD calculations, varying from the detailed to the numerically simplified, fast models, when applied for the modelling of the basic structures and various combinations, subjected to the oscillatory flow?

Cooperating company

SINTEF Ocean

Supervisor: Prof. Trygve Kristiansen

Department of Marine Technology • Faculty of Engineering

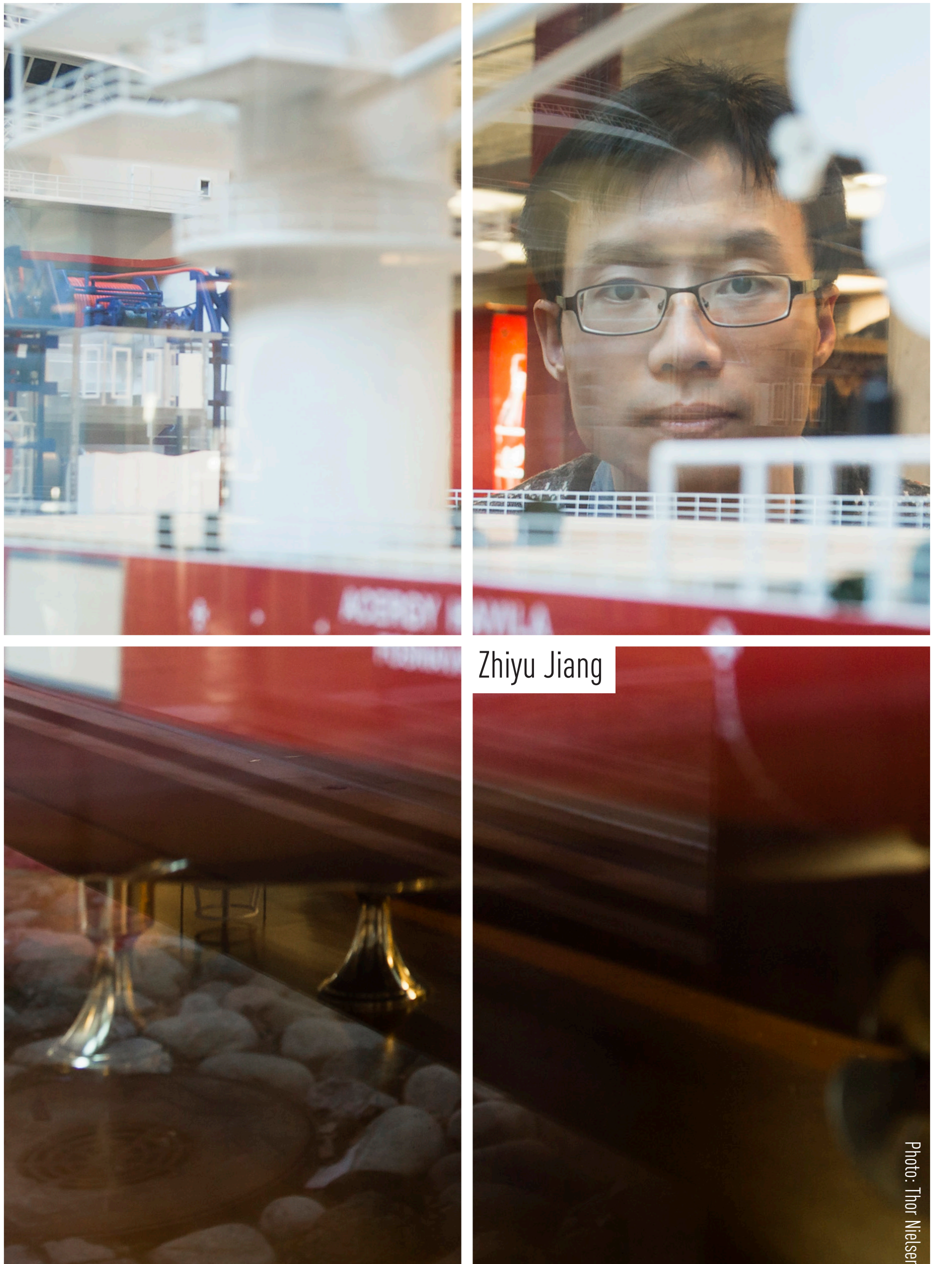


Photo: Thor Nielsen

Title

Efficient and accurate numerical methods and models for dynamic response analysis for installation of offshore wind turbines

Research topics

When using a floating vessel to install wind turbine blades or rotor-nacelle assembly, dynamic behaviour of the coupled system under simultaneous wind and wave loads are complicated. It is challenging to accurately model such floating system and predict the dynamic responses for design of the installation mechanism and system. The purpose of this study is to develop accurate numerical methods and models to analyse the actual installation procedure and to obtain the system responses for design check. The following case studies will be considered.

- Advanced modelling and analysis of the installation system for a pre-assembled rotor-nacelle-tower using the novel catamaran developed by NTNU Ålesund for design check and for validation of the numerical models used in the real-time simulation. The focus will be on modelling of the coupled system of the catamaran vessel, rotor-nacelle-tower and lifting mechanism.
- Conceptual design and optimisation of the very large floating dock concept for installing pre-assembled rotor-nacelle-tower system.
- Modelling of floating installation vessels to study the effectiveness on roll motion reduction using various damping devices (such as flopper-stopper, anti-roll tank).

Industrial goals

- To assess the feasibility of novel installation methods for a pre-assembled rotor-nacelle-tower system
- To reduce the roll motions of floating vessels to increase the weather window for installation

Scientific questions

- How to accurately model the coupled system of a floating installation vessel, blades or rotor-nacelle-tower assembly and a bottom-fixed or floating foundation and predict the dynamic responses under stochastic wind and wave loads?
- How to address the hydrodynamic and structural design aspects of a very large floating dock?
- How to reduce the roll motions of a floating installation vessel by passive or active damping devices?

Innovations

- New numerical methods and models for dynamic response analysis of installation systems

Cooperating company

OSC, DNV-GL, Ocean Installer, Statoil

Supervisor: Zhen Gao

Co-supervisor: Karl Henning Halse

Mats Jørgen Thorsen

Title

Coupled dynamic analysis of subsea mining riser systems.

Research topics

- Build a numerical model that allows coupled dynamic analysis of long riser systems applied in subsea mining operations
- Integration of time domain VIV model in SIMA
- Integration of 1D flow model in SIMA

Industrial goal

To contribute towards positioning the Norwegian Maritime industry in the forefront wrt. commercial harvesting of subsea minerals

Scientific questions

How will transients related to start-up and operation of mining riser system contribute to riser response?

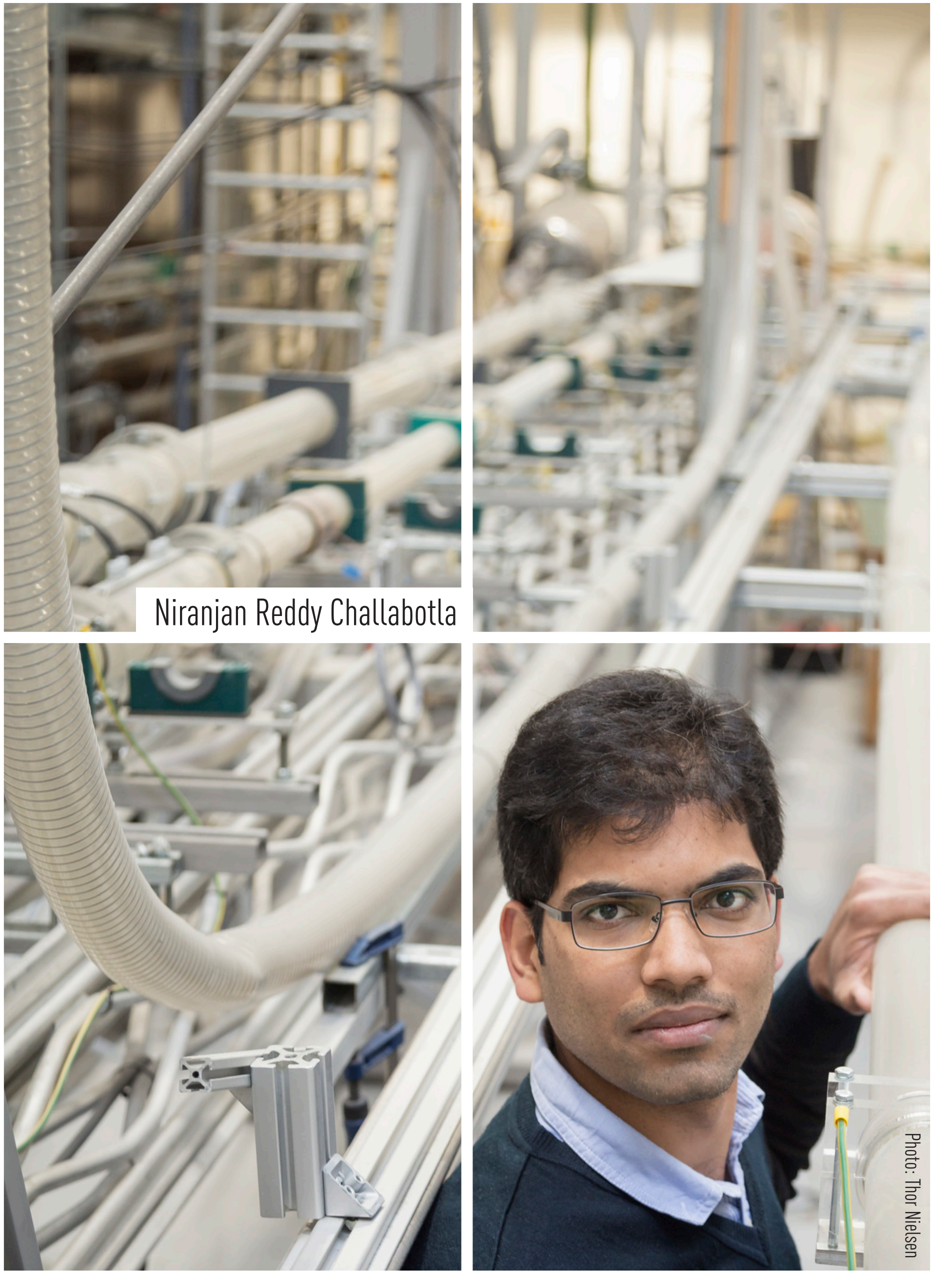
Innovations

A framework for performing dynamic response analysis of long riser systems with internal and external flow.

Supervisor: Svein Sævik (IMT, NTNU)
Co-Supervisor: Ole J. Nydal(IPT, NTNU)

POSTDOC

Department of Energy and Process Engineering • Faculty of Engineering



Niranjan Reddy Challabotla

Photo: Thor Nielsen

Title

Coupled dynamic analysis of subsea mining riser systems.

Research topics

- Tflow model to include particles and three phase flow with compressible gas (gas-lift scenarios).
- Integration of 1D flow o extend the 1D model in SIMA

Dynamic pipe flow modelling for Ocean Mining Lift System

Lifting of particles in long pipes from the sea bed to the surface is a challenging problem in deep sea mining. Many correlations were proposed in the literature for prediction of the pressure drop in horizontal and inclined pipes. Most of these correlations were semi-empirical and valid for steady state liquid-solid two-phase flows and particular range of particle parameters. The validity of these correlations is not well established in the application of deep-sea mining, where the particle size is larger and the fluid flow in pipe is highly transient. Recently, there is an increased interest towards better understanding of the particle transport in deep-se mining application. TECHNIP has developed transient flow assurance model FASST (Flow Assurance Simulation for Slurry Transportation) for design and monitoring of large particles transportation in liquid-solid riser systems (Beauchesne et al., 2015). Different mechanisms leading to riser blockage during the transport of particles in vertical hydraulic lift were reported by experimental and 1D models (van Wijk, 2016).

Dynamic flow conditions may occur during operations, and the structural pipe dynamics may also be influenced by the internal flow dynamics. The current postdoctoral candidate is focusing on extension of a 1D dynamic flow model (Sluggit) to include particles (Kjeldby, 2013). The proposed flow model will be based on a bubble tracking method which has been developed for analysis of flow transients in multiphase pipelines (based on C++, semi-implicit, moving grid). The developed dynamic flow model will be coupled with the structural pipe model. At later stage, flow model will be extended to investigate the feasibility of the gas lift system for deep sea mining application.

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Industrial goal

To contribute towards positioning the Norwegian Maritime industry in the forefront wrt. commercial harvesting of sub-sea minerals.

Scientific questions

How will transients related to start-up and operation of mining riser system contribute to riser response?

Innovations

A framework for performing dynamic response analysis of long riser systems with internal and external flow.

Supervisor: Ole J. Nydal (IPT, NTNU)
Co-Supervisor: Svein Sævik (IMT, NTNU)

Photo: Summørsposten, Staale Wattø

Communication and dissemination activities

The SFI MOVE home page is frequently updated, see http://www.ntnu.edu/move

The project has arranged following main conferences/ workshops in 2017:

- Marine Operations Forum, February 7
- Next Generation Simulator Technologies (OSC and NTNU), April 4
- Spring conference, April 5
- Workshop – PhD and Postdocs, October 9–10
- Autumn conference, November 22

Subsea Lifting Operations, 5th–6th December 2017, Stavanger:

Hans Petter Hildre, Karl Henning Halse, Mia Abrahamsen-Prsic and Frøydis Solaas presented the results from the SFI-MOVE.

NMK II in Ålesund:

NTNU officially opened the maritime education and training centre, as well as a research center, at NMK II 22.11.2017. The centre has 200 m2 and includes more than 20 simulators.

The centre is designed to do research on autonomous and semi-autonomous vessels and operations. Scenarios can be set up and different technologies can be compared. The centre also includes a technology to explore the next generation on-shore control centres for marine operations.

Digital Twin, a new project at NTNU

Digital transformation is a hot topic at present. Digital Twin integrates sensor technology, IIoT, analytics, simulation technology, artificial intelligence, BigData, and satellite communication. A digital twin is a virtual model of a physical component or system which includes TLC information needed throughout the value chain. Digital Twin integrates artificial intelligence/machine learning and analytics to living simulation models that continuously learns and updates itself from multiple data sources to provide real-time working conditions. These learning systems learn from themselves in operation, as well as input from experts, and are used to optimize design, manufacturing, operations and service.

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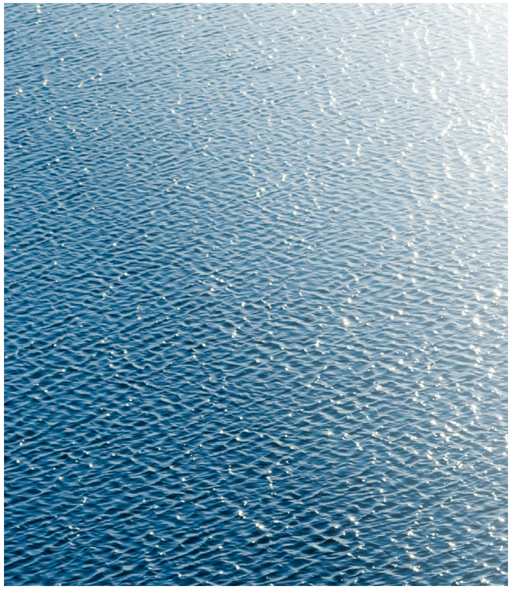


Master's degrees

Name	Sex M/F	Topic
Aurelien Lorenzo Edy	M	Time domain simulations of wind turbine blade installation using a floating installation vessel
Rui Xu	M	Stress analysis of a monopile foundation under the hammering loads
Muhammad Abu Zafar	M	Design and analysis of a semi-submersible vertical axis wind turbine
Sevyllen Kistnen Appiah	M	Analysis of the parameteric instability of the STC combined wind and wave energy concept
Xiao Liu	F	Numerical modelling and simulation of floating oil storage tanks considering the sloshing effect
Tobias Borgenhov	M	Vessel roll. Investigation of roll damping on an FPSO with sponsons and bilge keels
Prabhu Bernard	M	Installation of Offshore Wind Turbin on Floating Foundation using NX
Thor Erling Tangen	M	Towing tank: Mechanical design, hydrodynamical resistance testing and verification
Yu Feilong	M	Gangway control system
Siren Therese Thorsen	F	Time domain versus frequency domain VIV modelling with respect to fatigue of a deep water riser
Weitan Zhou	M	Optimization of passive heave compensation during Subsea Factory heavy lift operations

Accounts

The tables show the distribution of funding and costs in SFI MOVE for 2017. The funding plan shows where the funding comes from, and the cost plan shows where the research activity has been carried out.

Project 1 – Low Cost Offshore Wind Installation and Maintenance – was completeted in 2016

All figures in 1000 NOK

Funding		Project 2	Project 3	Project 4	Project 5	Lab/Dissemination	Management	Total
The Research Council		3592	348	2565	4248	20	1219	11992
The Host Institution, NTNU in Ålesund		1528	1477		209			3214
Research partners:		2910	339	53	185			3487
	NTNU	2065		53	161			2279
	SINTEF	845	339		24			1208
Enterprise partners:		2277	1257		955	400		4 889
Total		10307	3421	2618	5597	420	1219	23582

Costs		Project 2	Project 3	Project 4	Project 5	Lab/Dissemination	Management	Total
The Host Institution, NTNU in Ålesund		1917	1709		838	420	1135	6019
Research partners:		7513	1355	2618	4204		84	15774
	NTNU	4133		2618	4107		84	10942
	SINTEF	3380	1355		97			4832
Enterprise partners:		877	357		555			1789
Public partners								
Equipment								
Total		10307	3421	2618	5597	420	1219	23582

Name of active projects in 2017:

Project 2: Subsea: Safe - All Year - Cost Efficient Subsea Operation
Project 3: Demonstration of State of the Art Simulation Technologies and Virtual Prototyping as a Common Approach from Design to Operation
Project 4: Exploration of Technoligies to Develop Seabed Mining as a New Business Area
Project 5: Installation of Offshore Wind Power Systems
RA 5: Lab/Dissemination
RA 6: Management

Marine Operations Forum

Ålesund, February 7

Av Else Britt Ervik

Florian Sprenger (right), Sintef Ocean, was in charge of the first Marine Operations Forum. Here together with Hans Petter Hildre (left), Centre Director SFI MOVE

The Marine Operations Forum has been established in SFI MOVE to provide a platform for dialogue and interaction between researchers and experts from the industry on an annual basis.

The first forum was in February

The first forum has been held on February 7th 2017 at NTNU Ålesund, focussing on performance indicators for marine lifting operations. 30 experts from ship design companies, ship owners, operators, oil companies, crane manufacturers and classification societies gathered for one day to discuss criteria that influence the performance of marine lifting operations.

All provided valuable experience and views

A list of technical, safety, crew related, environmental and economic criteria has been established and weighting factors for the different criteria have been proposed. In this unique setting, all participants provided their valuable experience and views, working towards a commonly accepted set of criteria and weightings.

The outcome of this workshop is an important milestone in research area 1 of SFI MOVE, 'Vessel Performance'.

Spring Conference

Ålesund, April 4–5

SFI MOVE's Spring Conference was held on Tuesday 4th and Wednesday 5th of April. The first day was an open conference for which OSC was the main organizer, in co-operation with NTNU. Some of the possibilities that simulation can hold in the future were presented here. The day after was a closed conference for the partners in SFI MOVE. The programme for this day consisted of a presentation of all the ongoing projects in SFI MOVE. Both days were held at NMK's premises.

Agenda for 4th April – Open conference:

NEXT GENERATION SIMULATOR TECHNOLOGIES

- 12.00 – 12.30 Registration
- 12.30 – 16.00 Open conference in simulator technology
- 16.00 – Demonstrations

Agenda for 5th April – Closed conference:

09.15–14.00 Presentation of the SFI projects

- Subsea: Safe – All-Year – Cost Effective Subsea Operations, Ole David, SINTEF
- Vessel Performance, Florian Sprenger, SINTEF
- Virtual Prototyping; Simulation Technology and Virtual Prototyping as a Common Approach from Design to Operation, Lars Tandle Kyllingstad, SINTEF
- Seabed Mining; Exploration of Technologies to develop Seabed Mining as a new Business Area, Svein Sævik, NTNU
- OW; Innovative Installation of Floating Wind Power Systems, Karl Henning Halse, NTNU

This was the first of two permanent annual conferences in SFI MOVE. The conferences are important in order to give the partners an arena where they can meet, exchange experiences and discuss various future solutions within the professional areas the project covers.

Workshop

PhD and Postdocs

Ålesund, October 9–10

The students presented their work and the group discussed possibilities for innovations. Hans Petter Hildre, Karl Henning Halse, Trygve Kristiansen and Henning Borgen participated from the research team.

On 10th of October we visited Vard in Søvika. We spent one day onboard a fantastic diving vessel. Ivar Knutsen from Vard explained all details about the vessel. We are all impressed.

Agenda 9th of October

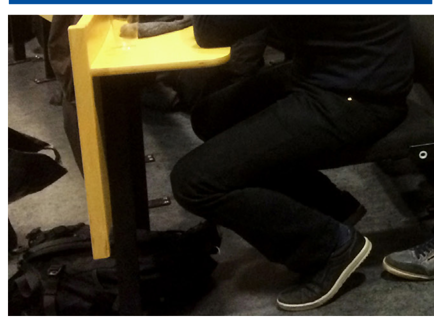
- Presentation of Innovation Plan (updates)
- 10–15 minute presentation of ongoing work (PhD and PD)
- Tour at campus
- Dinner

Agenda 10th of October

- Visit on Vard ship yard

Autumn conference

Ålesund, November 22



Agenda

10.00 Introduction, Innovation Plan etc.
Centre director: Hans Petter Hildre

10.30 Subsea: Safe – All-Year – Cost Effective Subsea Operations
Project leader: Ole David Økland, Sintef Ocean

11.30 Virtual Prototyping (VP); Simulation Technology and Virtual Prototyping as a Common Approach from Design to Operation
Project leader: Lars Tandle Kyllingstad, Sintef Ocean

13.00 Seabed Mining; Exploration of Technologies to develop Seabed Mining as a new Business Area
Project leader: Svein Sævik, NTNU

14.00 Innovative Installation of Wind Power Systems
Project leader: Karl Henning Halse, NTNU

15.00 Vessel Performance
Project leader Martin Gutsch

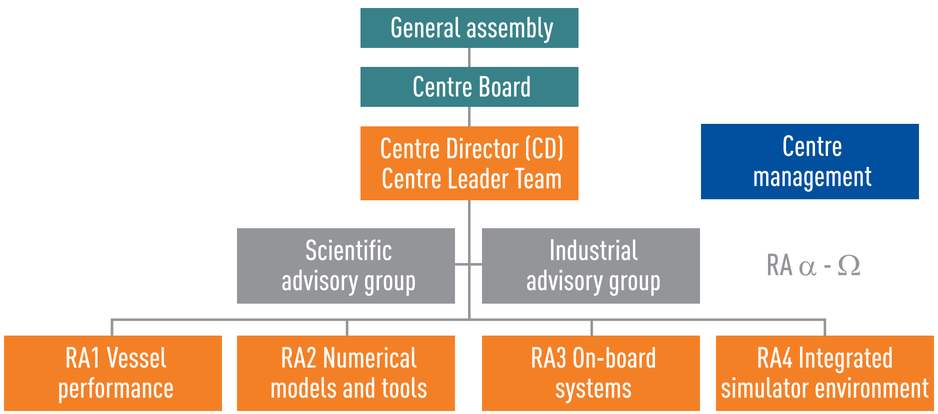
Guided tour and demonstrations at NMK II.

Research organisation

The following research partners were involved in the beginning of 2017:

- NTNU in Ålesund (former Aalesund University College)
- NTNU
- SINTEF Ocean

Aalesund University College has become a part of NTNU and MARINTEK and SINTEF Fisheries and Aquaculture has become SINTEF Ocean. We are very pleased for the restructuring of the research partners in few and strong organisations. *The project is organised as show in the figure.*



Organisation chart

The Board of the Centre has the following members:

- Arnt Olufsen, Chairman (Statoil)
- Tore Ulstein (Ulstein Group)
- Svein Kleven (Rolls Royce Marine)
- Hans Petter Hildre (NTNU in Ålesund)
- Sverre Steen (NTNU)
- Harald Stenersen (Havila)
- Halvor Lie (SINTEF Ocean)

Centre Director:

Hans Petter Hildre, Professor, Head of Department of Ocean Operations and Civil Engineering, NTNU in Ålesund

Administrative key personnel:

Magnhild Kopperstad Wolff, Finance & Administrative Coordinator, SFI MOVE, Department of Ocean Operations and Civil Engineering, NTNU in Ålesund

Industrial Advisory Board:

- Runar Stave, Olympic
- Harald Stenersen, Havila
- Per Ingeberg, Rolls-Royce Marine
- Bjørnar Vik, Rolls-Royce Marine
- Joel Mills, OSC
- Erling Myhre, Statoil
- Ken Nilsson, Ocean Installer
- Børge Nakken, Farstad
- Ove Bjørneseth, Vard
- Henning Borgen, SINTEF Ocean/SINTEF Ålesund
- Per Erik Dalen, ÅKP/GCE Blue Maritime

Industrial partners:

Two of our partners, Statkraft and Cranemaster, decided to withdraw from SFI MOVE from January 2017. A third partner, EMAS-AMC, closed the business in February 2017.

The industrial partners in the project in 2017 were:

- Farstad Shipping
- Olympic Shipping
- Havila Shipping
- Rolls-Royce Marine
- Ulstein International
- ÅKP/GCE Blue Maritime
- OSC
- Vard
- NTNU Ocean Training
- Statoil Petroleum
- EMAS-AMC
- Ocean Installer
- DNV-GL

The project leaders are:

Project	Project Leader	Deputy project leader
Subsea	Ole Økland, SINTEF Ocean	Gaspar Henrique, NTNU
Virtual Prototyping	Lars Tandle Kyllingstad and Henning Borgen, SINTEF Ocean	Zhang Houxiang, NTNU
Mining	Svein Sævik, NTNU	Gaspar Henrique, NTNU
Offshore Wind	Karl Henning Halse, NTNU	Zhen Gao, NTNU

Campus Ålesund