University of Stavanger

THE NATIONAL IOR CENTRE OF NORWAY

Annual report
2020

The 2020 partners

University of Stavanger

NORCE

IFE

NEPTUNE ENERGY

wintershall dea

vår energi

HALLIBURTON

Schlumberger

ConocoPhillips

Lundin Norway

equinor

AkerBP

Observers

With funding from The Research Council of Norway

NORWEGIAN PETROLEUM DIRECTORATE

petoro

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About

The National IOR Centre of Norway provides solutions for improved oil recovery on the Norwegian Continental Shelf through academic excellence and cooperation with the industry.

The world needs energy. Up to present day oil and gas have contributed to the primary energy by more than 80 %, and even in the 2-degree scenario of the United Nations more than 50 % of the total energy must come from oil and gas. On the Norwegian Continental Shelf, more than 50 % of the total discovered resources are still left in the ground. By extracting most of the discovered resources using existing infrastructure, we protect the environment while utilizing resources in the best possible way.

The National IOR Centre of Norway provides cost efficient and environmentally friendly solutions for improved oil recovery on the Norwegian Continental Shelf through academic excellence and close cooperation with the industry.

APPROACHING THE FINISH LINE

Awarded by the Research Council of Norway (RCN) after a national competition, the Centre started up in December 2013. We were granted 5 + 3 years of financial support by RCN. We are now in the last year of the Centre's lifetime.

University of Stavanger is the host of the Centre, and the research institutes NORCE (formerly known as IRIS) and IFE are our research partners. Several other national and international research groups, and 9 oil and service companies, complete the Centre's list of partners and collaborators.

The researchers in the Centre work actively in order to improve the oil recovery, whilst reducing costs and mitigating environmental impact. To achieve this goal, it is important that all stakeholders work together, and The National IOR Centre of Norway is an important arena for doing exactly this.

OVERALL AIM

The National IOR Centre of Norway will contribute to the implementation of cost efficient and environmentally friendly technologies for improving oil recovery on the Norwegian Continental Shelf.

SECONDARY OBJECTIVES

- Robust upscaling of recovery mechanisms observed on pore and core scale to field scale.
- Optimal injection strategies based on total oil recovered, economic and environmental impact.
- Educating some 20 PhDs and 6 postdocs during the eight-year period, as well as 50 MSc students per year*

  *by the end of 2020, this number is almost 30 PhDs and 20 postdocs

THEME 1: MOBILE/IMMOBILE OIL & EOR METHODS

In theme 1 the main goal is to understand, model, and upscale the microscopic and macroscopic displacement efficiency when various enhanced oil recovery (EOR) fluids are injected into a porous rock. EOR fluids interact with the rock, alter primary mineral phases, and their surface properties. Some EOR fluids are non-Newtonian (e.g. polymeric fluids) and behave highly non-linear in complex and time-dependent flow, which is relevant for porous media. Other injection fluids, such as Smart Water (or low salinity water) interact with the minerals to alter wettability in the reservoir.

To understand these processes, and to solve related challenges we work at the submicron scale to characterize the rock before and after flooding, and to quantify the changes induced by the injection water. We also work at core scale to investigate wettability and wettability alteration processes. And the dynamics of polymeric liquids are investigated experimentally by performing experiments in porous material at various scales. The experimental results are interpreted using molecular dynamic simulations, methods based on statistical physics, and by extending Darcy's law. A multi-scale understanding of the EOR processes secures that the reservoir scale models we develop are consistent with the underlying physical and chemical processes taking place in the pore space. This, in turn, allows us to evaluate, in a robust way, the potential of EOR operations for realistic cases.

The EOR methods based on Smart Water are in principle environmentally-friendly, as they don't contain extra chemicals. The environmental impact of using added chemicals, such as polymers, is addressed through an improved understanding of the optimal amount of chemicals needed to efficiently displace the oil and the fate of the chemicals from the injector to the producer.

THEME 2: MOBILE OIL – RESERVOIR CHARACTERISATION TO IMPROVE VOLUMETRIC SWEEP

In theme 2 we focus on improved reservoir management by developing improved tools for uncertainty quantification, simulation, history matching, optimization, prediction, and decision making. This is done by; integrate information from of all types of data (such as pressure data, production data, seismic data, tracer data, geo-physical data, and geological data into the field scale simulation models) in our work flow; by developing improved simulation tools capable of handle/simulate the complexity of different improved oil recovery (IOR) methods; and by developing new and improved tracers.

We put emphasis on real fields and aim to develop methodologies that ease the decision making of a petroleum producing reservoir. The aim is to develop new and improved methodologies that will support the evaluation and decision making with regards to IOR/EOR pilots at the Norwegian Continental Shelf. This addresses the potential of producing the resources in unswept areas as well as mobilizing the trapped resources in swept areas. The research is focusing on challenges for the entire Norwegian Continental Shelf while demonstrating the improved methodologies on real field cases in close cooperation with the industry partners.

These are the Centre tools and methods we deliver to our industry partners. Some tools are continously used today, some will be of great importance beyond 2021.

UPSCALING TOOLS

What are the most important parameters from smaller scales to describe flow on a larger scale? Environmentally friendly chemical EOR methods have proven their potential on core scale. But, additional oil produced at the core scale does not necessarily imply that the field recovery will be similarly increased. Cores are usually 5–7 centimetres in length and molecular diffusion and end-effects could be important, contrary to field conditions. In The National IOR Centre of Norway we have developed a core scale simulator, IORCoreSim, which is capable of simulating most of the experimental data on EOR core flooding. The mechanisms for the release of oil are based on physical and chemical interactions. The models in the simulator are calibrated to numerous core scale experiments.

Parallel to this development is the OPM initiative (Open Porous Media) and IORSim, which are full field simulators. The models developed at core scale cannot be directly taken into our field scale simulators, simply because the field scale simulators use grid blocks that are too large. A large grid block smears out chemical gradients, and the simulators will give a totally unrealistic prediction of the IOR potential.

The main focus the last two years of the Centre lifetime is to upscale the models in IORCoreSim to field scale, and give a more correct picture of the IOR potential using models that are calibrated (through IORCoreSim) to lab data.

To this end we have launched a new upscaling project, with the main objective to develop a workflow to ensure a robust upscaling of recovery mechanisms observed on pore, and core scale to field scale.

FIELD APPLICATION TOOLS

The National IOR Centre of Norway will deliver methodology that can support the evaluation and decision making for IOR pilots on the Norwegian Continental Shelf. Research and development regarding different methods are performed in the Centre:

- New tracers for reservoir characterization and estimation of remaining oil in water-swept areas are developed to evaluate potential for IOR and estimate the effect of IOR operations.
- Methodologies that contribute to optimization of injection strategies with the aim to increase oil recovery, maximize economic benefit and minimize environmental impact are developed.
- A 4D seismic history matching workflow is developed to improve reservoir management, improve uncertainty quantification, and to contribute to improved decision making and optimal strategies leading to improved volumetric sweep.

An important deliverable from the Centre will be well-documented and verified methodologies for evaluation of the IOR potential. It is also important to combine and integrate different methods to gain increased knowledge and better methodologies, this is emphasized in all projects. The project on optimization will focus on delivering an integrated study in the two last years. A significant aspect for implementation of IOR on the NCS is evaluation of environmental risk. The Centre will develop and implement risk analysis methods and models to assess and evaluate overall environmental impacts and risks associated with different IOR solutions resulting from our research activities.

Greetings from the Director

2020 has been a special year for the whole world and for everyone. Many of us are lucky to continue working from home office, and to some degree working from our offices and university campus in shorter periods. We also fortunately managed a larger gathering right before the lock down before early March. Despite of all the challenges, I am proud of our progress in this exceptional time thanks to additional effort and hard work from all of the centre collaborators. We are able to complete 4 PhD defends, all with digital media connecting committee members from the different continents at different time zones, occasionally with a few persons on-site to support and celebrate your achievements. We miss the traditional congratulation cakes and speeches after your defence. I want to use the opportunity here to give a great salute, and wish you all good luck either in oil and gas industry or academy to continue your career.

Centre Director Ying Guo. Photo: Marius Vervik

As we are approaching the final year of the Centre, we are now focusing our effort to complete the planned projects and to deliver the research results to our industrial partners for potential field applications. We have more frequent meetings and workshops with users through our Delivery Forums for various technical domains, these forums are additional dissemination channels for our final deliverables of knowledge and tools to improve the field implementation of IOR technology. This is time to harvest our almost 8 years of research work, and demonstrate how we can contribute to maximising resource utilization and value creation in the transition to a sustainable society. We will do our best to fulfil the expectation of what we were set out to achieve within the Centre, and we are looking forward to reach our goals.

Time is changing, the Net-Zero climate gas emission by 2050, combined with cost-efficiency and further reduction of environmental impact from Oil and Gas industry, will need new knowledge and technology development, smart solutions and skilled human resources to reach these ambitious goals. We are part of the solutions, and our 'Joint forces to recover more' will lead to many good solutions, now and in the future. I am proud to be part of this journey together with all of you.

Greetings from the Chairman of the Board

In the last year, The National IOR Centre of Norway has built on the strong communication lines with the industry. Despite the social distancing imposed by the Covid-19 situation, digital arenas have effectively been used to clearly define deliverables from the various activity streams and allowed a continued knowledge transfer from the Centre to its partners through Delivery Forums.

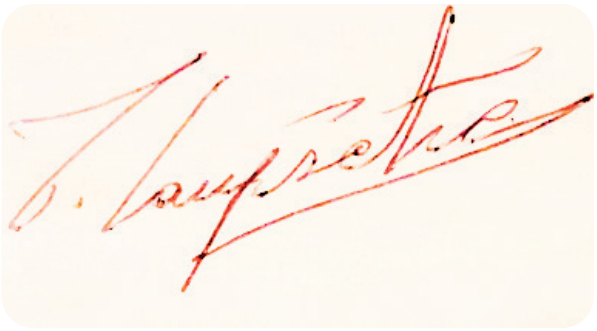
The Centre is helping to define updated best practices in assessing Enhanced Oil Recovery strategies with attention to all the steps in the process, including core material handling, assessments of the microscopic mechanisms through experimental procedures and newly developed core models, and upscaling tools and methods. The Centre has also taken a leading role in defining requirements and supporting the application for a national large scale testing facility, which would allow a further derisking of the field implementation of such EOR strategies.

In addition, the Centre is providing new data types and workflows to better resolve the remaining potential in the fields. An example of this is by improving ensemble modelling integrating more data types while improving open source softwares to enable a stronger understanding of the remaining uncertainty space.

Entering the last year of activity for the Centre, focus is on concluding the current efforts via deliverables that can be directly used in the industry, including a stronger link across the various activities to benefit from synergies between these through consistent workflows.

Chairman of the Board Thierry Laupretre. Photo: Marius Vervik

Finally, the Centre is maturing research themes and longer-term options to continue benefiting from the competence developed in the Centre, the tight links with the industry and the continued development of new talents that will help the energy efficient development of fields in the times to come.



Greetings from the Head of Technical Committee

2020 has been an unusual year across the whole industry, with new work situations as home offices and digital meetings. Still, in 2020, The National IOR Centre of Norway has progressed several key activities to reduce the gap between the industry and academia.

In 2020 four new forums were formed to further strengthen the dialog between industry and researchers, and to ensure alignment in the deliverables from the centre. The Centre management has set up delivery forums for ”Wettability and Smart Water EOR”, ”Polymer”, ”Upscaling” and ”Field application. These forums meet on a regular basis. The forums will also further develop the collaboration between different projects and research groups internally within The National IOR Centre of Norway.

For the past years, the IOR Centre has developed several numerical simulators to help the industry to reduce uncertainty in EOR projects. These simulation tools have been made more user-friendly and are now being more actively pushed out to the industry.

For 2021 the focus will be on finalizing the ongoing projects and combine the results into workflows and deliverables that can be adopted by the industry. The tools and workflows developed by the IOR Centre, together with the cross disciplinary collaboration, will be a strong foundation for the Centre to continue beyond 2021.

Head of Technical Committee Robert Moe. Photo: Marius Vervik

NORCE is a research institute, with expertise in a wide range of fields. Researchers within the Energy Department of NORCE run several of the major projects in the Centre.

The energy group at NORCE conduct research in the field of oil/gas and renewable forms of energy, with a focus on cost-efficient, safe energy production that guarantees the lowest CO_2 footprint possible during the green shift.

IMPORTANT PROJECTS

Researchers at NORCE are involved in several major research projects in the Centre.

- Task 1: The project DOUCS-Deliverable of an Unbeatable Core Scale Simulator aims to develop a tool for improved simulation of EOR processes at the core scale. The project Core plug preparation procedures addresses the importance of representative wettability conditions in SCAL and EOR -experiments and aims to develop methods to determine whether reservoir core plugs are contaminated by mud.
- Task 3: The objective of the pore scale task is to identity mechanisms that influence fluid transport, chemical reactions, and oil recovery. The main topics in this task have been to study the behavior of polymers and the effect of water chemistry on the strength and structure of the pore space.
- Task 4: The IORSim project is a collaborative effort between IFE, NORCE, and UiS to develop a simulator that can bridge the gap between the research prototype simulators and industry standard reservoir simulators. The large (yard) scale project is led by Halliburton with a very good collaboration with activities in Task 1 and Task 5.
- Task 6: Improved modeling methodology and simulation capabilities for IOR are important to perform reliable pilot and full field simulations. In this project, we contribute towards the OPM simulation framework. This is an open source code able of handling industrial relevant models, which provides a platform for testing innovative reservoir simulation developments in general. We anticipate that the resulting improvements will lead to better decision making and, hence, improve oil recovery on the Norwegian Continental Shelf.
- Task 7: The economic feasibility of implementing new IOR methods on a field needs to be evaluated, preferably taking the uncertainty in the reservoir description into account. The evaluation will be based on history matched reservoir models. An important focus in this task is to develop better methods for full field history matching using 4-D seismic data using real data, an open data set for the Norne field and data from Ekofisk that has been made available for selected studies within the IOR Centre. The history matching is done using ensemble-based methods, but we consider use of different types of seismic data for inversion.

Randi Valestrand leads the IOR Centre work at NORCE.

IFE is a research institute within energy, health and industrial development located in Kjeller. IORSim and tracer technology are the most important IFE contributions in the IOR Centre.

IFE is an independent foundation and one of the world's foremost research communities on energy, located in Halden and Kjeller. They have developed unique skills over 70 years of researchers and international projects in their reactors and laboratories. Offshore, IFE has developed low-emission petroleum technology and advanced digital solutions for management, security and communication. The knowledge, innovation and development at IFE has created hundreds of billion NOK in values for Norway and improved safety, environment and climate both at home and abroad.

IMPORTANT PROJECTS

Researchers at IFE are involved in research projects in several tasks.

- Task 4: The IORSim project is a collaborative effort to develop a simulator that can bridge the gap between the research prototype simulators and industry standard reservoir simulators. Major achievement since last reporting is implementation of cross-flow in wells. Ongoing work: i) investigate further the coupling between IORSim and Intersect and ii) use Ekofisk water chemistry data to verify/calibrate IORSim iii) continue our work on the Snorre sector model to simulate silicate plugging.
- Task 5: The overall objective of this task is to improve and develop new tracer technology for in-situ determination of residual oil saturation (SOR) and for improved description of flow fields. Both tracers for investigating the swept volumes between wells (interwell examination) after some period of secondary oil production and for examine the effect of various tertiary recovery methods by push and pull operations in the near well region are developed. The targeted methods are aimed to produce valuable data for evaluation of the need for infill wells, conformance control and evaluation of the most efficient EOR method for a given oil field.

At present, several scientists and one PhD-student (Arun Kumar Panneer Selvam, started in March 2019) is involved in this task. Selvam is working with carbon quantum dots for fracture detection in interwell operations and with nano-carriers for passive water and water-oil partitioning tracers for SOR determination in the near-well zone. In addition, a team of scientists are working with new hydrolyzing ester compounds for near-well SOR determination.

Sissel Opsahl Viig leads the IOR Centre work at IFE.

The Scientific Advisory Committee (SAC) of The National IOR Centre of Norway met digitally to give their advice for the last year of the Centre's lifetime, and also beyond 2021.

FROM THE REPORT:

«We were impressed by how many of the ideas and advances developed with the IOR Centre are now being applied in other fields. You should celebrate this through a separate report (...) which focuses specifically on the scientific contributions of the preceding year and the planned scientific contributions for the following year.

We were interested to hear the plans to create an IOR Academy following on from the IOR Centre, however were not convinced that this is viable. It may have the support of the companies (who need engineers and scientists trained in IOR) but is unlikely to attract a sufficient number of students, as internationally the number of students wanting to undertake taught degrees or a PhD in petroleum engineering continues to fall. We note that the new computational geoscience degree offered by the University of Stavanger has been very successful in attracting students and recommend that IOR Centre be more visionary and wide ranging in their plans for the next Centre or Academy, perhaps based on ideas in this new course. Overall, the Centre should continue its short-term focus on performing excellent fundamental research whilst delivering high quality applied research that addresses the needs of its industrial partners. The medium-term goal should obviously be planning for the next phase, after the funding for the IOR Centre finishes whilst looking to the future and the transition to zero-carbon energy sources.

The committee recognises the wide scope and impressive achievements of the IOR Centre's existing research programme, combining both fundamental and applied research in the laboratory and computationally. As noted previously the Centre is clearly more than the sum of its parts. The team now need to develop a vision for the future that is wider than improving oil recovery in order to engage young people, to maintain both industrial and public support and ensure the long term growth of the Centre and the energy sector in Norway.»

MEETING THE RECOMMENDATIONS

To ensure consistent and integrated workflows and high quality deliverables from eight years of intensive work to the industry, the Centre management has set up delivery forums for "Wettability and Smart Water EOR", "Polymer", "Upscaling" and "Field application. These forums meet on a regular basis to make sure the research projects across tasks and themes are progressing in collaboration, to reach common goals with quality, and on schedule.

The IOR Academy (working name) was born as a spin-off initiative from the IOR Centre. The Academy aims to (reach the status of a centre with national responsibility to) preserve subsurface competencies at national level and contribute to recruiting students and further educating professionals motivated to develop new technologies and solutions for a low emission energy future. In order to do this, the Academy believes in the importance of combining solid general competencies, such as physical understanding, mathematical and statistical modelling, and computer programming, with knowledge in the subsurface domain. Students from mathematics, physics, chemistry, geology and applied data science, are the candidates targeted by the Academy. The idea is to expose students with more general and advanced competencies to problems related to the subsurface. On the

other hand, it is more and more evident that the competencies of the work force need constant updates and professionals in the oil and gas industry may need follow-up qualifications due to change of focus of the industry. The Academy intends to have a strong focus on subsurface knowledge combined with digital tools and methods.

The Academy graduate student will be equipped with skills which combine generic advanced knowledge with domain knowledge. Our focus is on applying existing knowledge and research results to existing datasets.

(...) the importance of combining solid general competencies, such as physical understanding, mathematical and statistical modelling, and computer programming, with knowledge in the subsurface domain.

The Scientific Advisory Committee: Yu-Shu Wu, Stephan Herminghaus, Bill Rossen and Ann Muggeridge. Photo: Elisabeth Tønnessen

The National IOR Centre of Norway prioritizes plans for legacy funding as we reach the final year. Below we list some possibilities for continuity of activity after the end of centre funding.

The oil and gas production will contribute to the energy mix for the coming years in transition to renewable energy. Implementing IOR methods is time-critical to maximize the national reserves exploitation on the maturing Norwegian Continental Shelf. The National IOR Centre of Norway must be prolonged to find the best IOR solutions and to educate the best personnel for the industry beyond 2021.

Time is changing, the Net-Zero climate gas emission by 2050, combined with cost-efficiency and further reduction of environmental impact from the oil and gas industry, will need new knowledge and technology development, smart solutions and skilled human resources to reach these ambitious goals.

INFRASTRUCTURE

The Research Council of Norway published their new roadmaps for petroleum research infrastructure in May 2020. The National IOR Centre's infrastructure application was listed as "worthy of support", and a new application was handed in November 2020.

"In the future, we expect increased efforts in research and technology development to reduce greenhouse gas emissions from offshore petroleum activity," is the message from the Research Council of Norway.

Going ahead, in the remaining time of the IOR Centre, we will focus on using our research results and competence acquired in the past seven years to contribute to IOR field implementations and to optimize late oil and gas life on the Norwegian Continental Shelf. In order to do this, we believe it is critical to test and fine-tune our models with realistic testing at laboratories that best represent field operations, a kind of field pilot onshore. In this way, we will reduce the risk and uncertainties for real field operations. We are very determined to build a national IOR infrastructure with open access to everybody who wants to try out their IOR methods and equipments or instruments.

TIME-CRITICAL

To implement the research results from IOR Centre for field application without public funding, will slow down the progress and we will lose time for meeting the challenges for IOR from mature fields. Another important puzzle in this picture is the urgent need for reducing CO2 emission which is even more time-critical from a climate point of view. Now, with CCS on the Norwegian Continen-tal Shelf as part of the solution, and IOR including CO2-EOR could be a stepping stone to the green transition of the industrial activities on NCS.

NCS2030

National Centre for Subsurface Understanding
and Resource Utilization toward 2030

IFE

Has delivered ideas for more than 70 years and has played a key role in the development of Norway as an energy producer, providing solutions which are daily used by the oil & gas industry.

NORCE

A research institute covering future need for E&P, performing research and deliver solutions in the field of oil & gas and renewable energy, with a focus on safe and sustainable energy production.

University of Stavanger

Department of Energy Resources is a leading expert on education and research within subsurface understanding and reservoir management for competence-building and value-creation at low CO_2-emission.

UiS, NORCE and IFE are continuing to join forces in petroleum research and subsurface competence. We have a long history of collaboration with industry and are successful in national research projects.

The Research Council of Norway (RCN) is planning to establish up to two new Research Centres for Petroleum from 2022 with its recently published call for proposal for PETROSENTER. The announcement is aimed at subsurface understanding, which is a topic area of high importance for value creation and the realization of remaining resources on the Norwegian shelf. The theme area is also important for plugging and shutting down wells.

From the call: ”The research should be aimed at increasing the resource and reserve base on the Norwegian continental shelf and being able to provide effects for value creation in the entire value chain from exploration, development, operation and closure. Scientific, technological and social science disciplines can be included. RCN expect that underground understanding will be more closely linked to digitalisation in the future and be an integral part of the industry’s toolbox for reducing greenhouse gas emissions from its operations.”

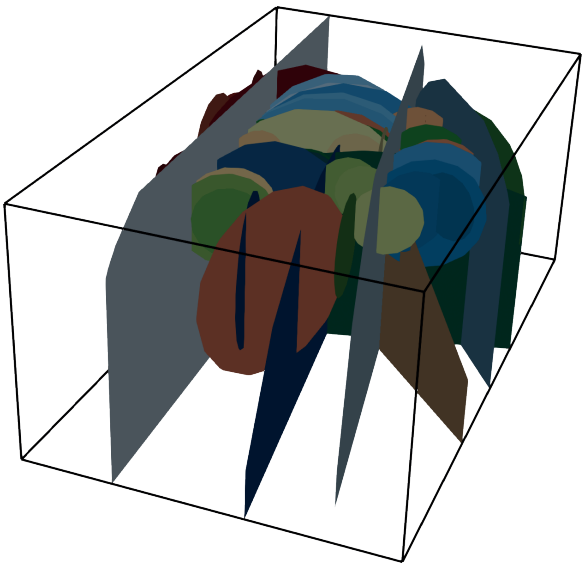
The IOR Centre research partners are now preparing an application for the petrosenter NCS2030 with main vision to maximise oil and gas resource utilization and contribute to the green transformation on the NCS. This new initiative will pave the path for continuing our research and innovation. The planned centre will continue to improve expertise in subsurface understanding forming scientific and innovation foundations for value creation.

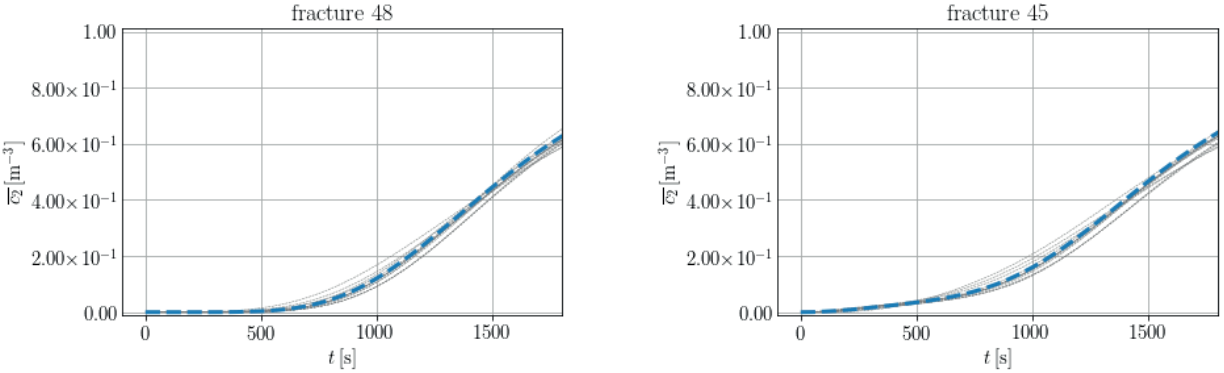
Implementing fracture models in the Open Porous Media simulator

Modelling and simulations of fractured reservoirs give rise to many challenges. This is partly due to the high aspect ratios and strong heterogeneities in the material parameters between the fractures and the rock matrix. In 2020, one of the focuses of task 6 in the IOR Centre has been to implement state of the art fracture models in the Open Porous Media (OPM) reservoir simulator (https://opm-project.org/).

We have developed a flexible framework that allows for an easy adaptation of different fracture models, which is demonstrated by the models currently implemented; the dual-permeability model and the discrete fracture matrix model. In the dual-permeability model the fractures are upscaled into an effective continuum where transfer terms take care of the mass exchange between rock matrix and fractures. This is a popular approach that also is available in many commercial simulators. In the discrete fracture model the fractures are included explicitly in the simulation domain, which allows the model to better capture the geometric effects of the fractures. The cost of this increased accuracy in the modelling is a more complex computational geometry.

A great deal of attention has been given to ensure that OPM can correctly capture the capillary barrier effects that occurs if the fractures have a different capillary pressure curve than the rock matrix. The fracture implementation in OPM has been thoroughly tested and benchmark against other computer codes on several difficult test cases. We have also run the first reservoir scale test case with explicitly included fractures. By the end of the IOR Centre the goal is that OPM will be able to run reservoir scale fractured simulations with multiphase fluids.





Fracture benchmark case setup shown in the top figure. The rock matrix is removed to reveal the fractures. The fracture color is arbitrary. The two plots show the evolution of the mean saturation in two of the fractures as obtained from OPM (dashed blue) and the benchmark results by Berre et.al. [2020] (gray).

Text: Runar Berge
postdoc task 6

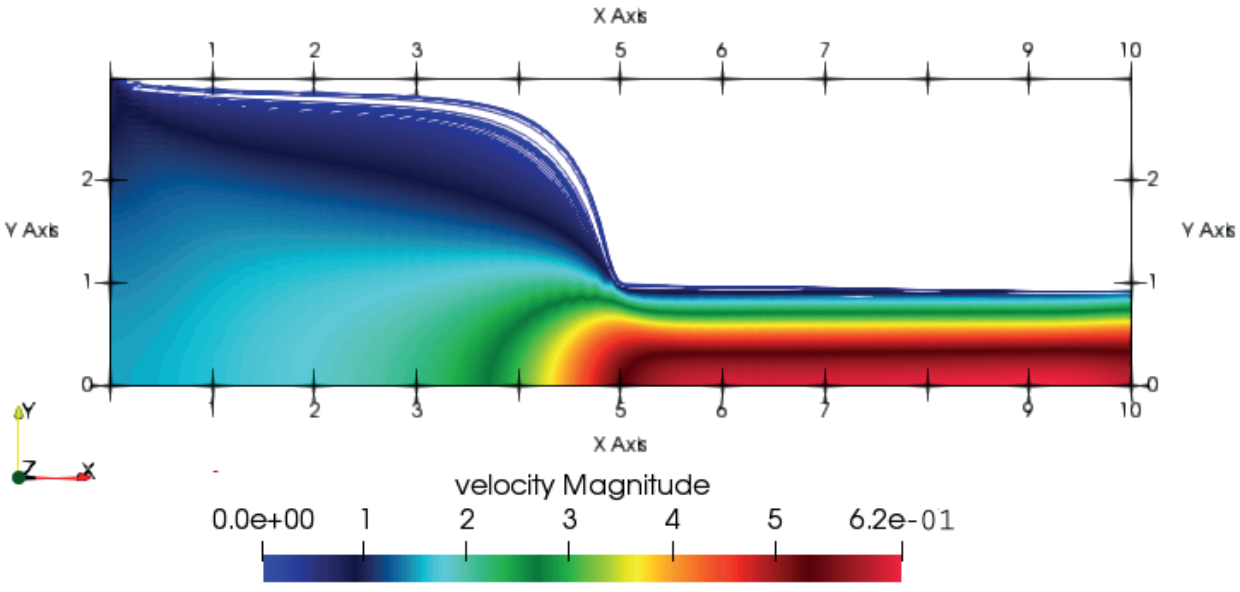
Simulation of non-Newtonian fluids models with applications to IOR

Non-Newtonian fluid flow modeling is of paramount importance in many industrial and medical applications from enhanced oil recovery (EOR) to blood flow in arteries and polymer processing. The behaviour of the non-newtonian flow is complex and requires a careful treatment of the physical processes involved as well as accurate and efficient numerical techniques.

We provided within the Distributed and Unified Numerics Environment (DUNE) software framework (https://www.dune-project.org/) a solver for direct numerical simulation of non-Newtonian fluids. As of the end of 2020, Quasi-Newtonian models, Finitely Extensible Nonlinear Elastic (FENE-P) models and Oldroyd-B models (equivalent to a fluid filled with elastic bead and spring dumbbells – https://doi.org/10.1098/rspa.1950.0035) have been implemented. As opposed to Newtonian (resp. quasi-newtonian) fluids where the stress tensor is a linear (resp. nonlinear) functional of the velocity and pressure fields, the non-newtonian viscoelastic models (e.g., FENE-P, Oldroyd-B) require considering another constitutive equation where the stress tensor is another unknown. Simulation of such problem class becomes quite challenging when the amount of fluid elasticity is highly increased. Thus, requiring stabilization techniques in order to avoid failure of the numerical simulation or spurious oscillations. Investigation of suitable solution strategies is ongoing. By the end of The National IOR Centre of Norway's lifetime, we aim at improving the accuracy by providing higher order discretizations techniques and more sophisticated solution strategies.

As a part of Task 6 of The National IOR Centre of Norway, this work falls completely in line with the aim to develop new and reliable methodologies that will support the evaluation and decision making with regards to IOR/EOR pilots at the Norwegian Continental Shelf (NCS).

Text: Birane Kane
postdoc task 6



Magnitude of velocity and streamlines for a viscoelastic (Olroyd) fluid flow in a 3:1 contraction geometry.

Projects studying nano-and micro-sized IOR-related features in rocks

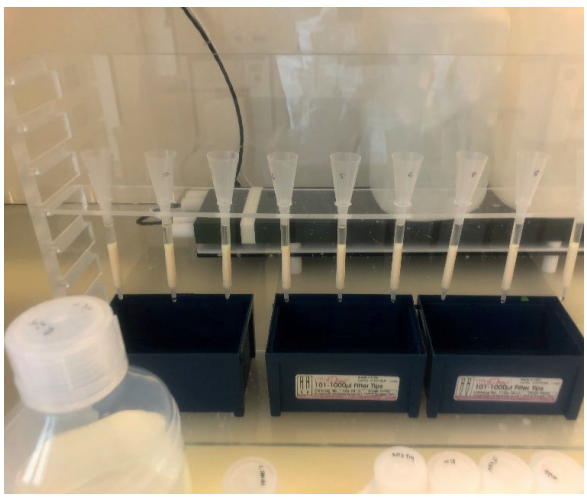
2020 started with a very exciting visit to the "Department of Earth and Planetary Sciences" at Yale University. PhD student Tine Vigdel Bredal and one of her supervisors, Mona Wetrhus Minde, spent a week visiting Dr. Noah Planavsky and his team, analysing stable isotopes to test if these can be used in the study of chalk. Unfortunately, the universities, both Yale and University of Stavanger, closed down shortly after our tests, but the results look promising, and we are looking forward to further studies on this subject that can help us understand the depositional environment of reservoir and onshore chalk.

We have several ongoing projects studying nano-and micro-sized IOR-related features in rocks collaborating with different laboratories internationally. Even though things are going slower this year, we are now preparing articles to present some of these findings and we have focused on the effects of flooding different minerals, such as calcite and dolomite, with IOR fluids. We are soon to complete our studies to look at relations between the amount of dolomite found in the reservoir rock and fluid-induced compaction experienced in the reservoir.

PhD candidate Ema Kallesten who has performed parts of her research under task 2, defended her thesis in December 2020. She has worked with reservoir rock mineralogy and the effects of fractures in low-permeability chalk. Her work has helped with a deeper understanding of reservoir chalk and given more parameters to choose the right analogues for further testing, and also better understanding of and modelling tools for the effects of fractures in chalk over time and under changing conditions.

Text: Mona Wetrhus Minde, task 2

The quantity of each element is very low, and you risk losing the content if the procedure is not followed correctly. Mona Wetrhus Minde is therefore fully concentrated when working.
Photo: Private



Tor Bjørnstad gives a brief introduction to tracer technology

Your work in the IOR Centre is dedicated to tracer technology for the petroleum industry. What exactly is a tracer?
We have, of course, a formal definition of the tracer concept, but I shall be somewhat careful here in not making things too complicated. Let me just say that a tracer is a physical or chemical component, mostly a molecular structure, that is added in minute amounts to a process where mass flow is taking place. The intension is to measure certain important governing parameters of the process. These can range from simple flow mapping (rates, directions and volumes) using passive tracers with no chemical or physical interaction to the monitoring of certain defined properties of the system by the use of active or interacting (or reacting) tracers.

In what way is tracers useful for the petroleum industry?
Tracers are used in nearly all stages in the petroleum industry from exploratory drilling, to reservoir evaluation, production allocation, processing of produced fluids in all stages and to pipeline transportation and fiscal metering of the final products. For our work in the IOR centre, we have concentrated mainly on development of methods for measurement of residual (or remaining) oil saturation (SOR) in water-swept reservoir sections between injection and production wells and in the near-well zone out to some 5-10 meters from the well. Such remaining oil saturation may be target for enhanced oil recovery (EOR) methods. Thus, our main aim has been to develop active, i.e. water/oil phase-partitioning, tracers. SOR may be deduced when such tracers are used in combination with passive water tracers.

In 2019 you got a new PhD candidate, Arun Selvam. What is he working on?
Arun is working on a brand new concept for measurement of remaining oil saturation in the near-well zone. It invoves the use of nanoparticles as tracer transport vehicles and the laboratory loading and in-field release of tracers from such particles. I have to admit that it is a risky project, but no risk – no gain!

What has been the most important results/findings in your work in 2020?
Without doubt the final confirmation of the performance of a new set og oil/water partitioning tracers to be used in well-to-well measurements of SOR in swept volumes between wells. This is based on the work of the PhD student Mario Silva, who has now submitted his Thesis for evaluation and defence.

Has the covid-19 pandemic affected your work? If yes, in what way?
Yes, unfortunately the Corona pandemy has affected negatively the work of the tracer group since is heavily based on experimental laboratory work. In periods, access to laboratories have been restricted. We have also experienced delayed delivery of special chemicals and consumable components which again has delayed the start-up of certain experimental work.

The IOR Centre is now in its last year with public funding. What deliveries will the industry partners get from your research group by the end of 2021?
The work in the tracer group during the past 7-8 years has produced a considerable amount of experimental results related to reservoir-associated tracer technology. The main and most immediate delivery will be a method with a new set of laboratory-qualified water/oil partitioning tracers for measurement of SOR in reservoir sections between wells. However, the project will continue some time into 2022 with dr-student Arun. It will be very exciting to see what results he can come up with for the mentioned new concept. Still, I think we in this project have some distance to travel before we, with full joy, can shout EURECA!

Tor Bjørnstad, leader task 5

With only one and a half years left of the first phase of the IOR Centre, it was time to concretize our deliverables to the industry. 26-27 May we arranged kick-off meetings for Delivery Forums.

The digital kick-off meetings were arranged to give our industry partners insight in the ongoing work of our PhD students and postdocs. The meetings were a success, with about 50 participants in each of them.

MAIN DELIVERABLES

To better illustrate the Centre's main deliverables and how our projects are integrated to manage and achieve the specifications of the work plan for 2020-2021, we have developed four main categories of deliverables:

- Methods & Mechanisms
- Upscaling
- Field Application
- Education & Dissemination

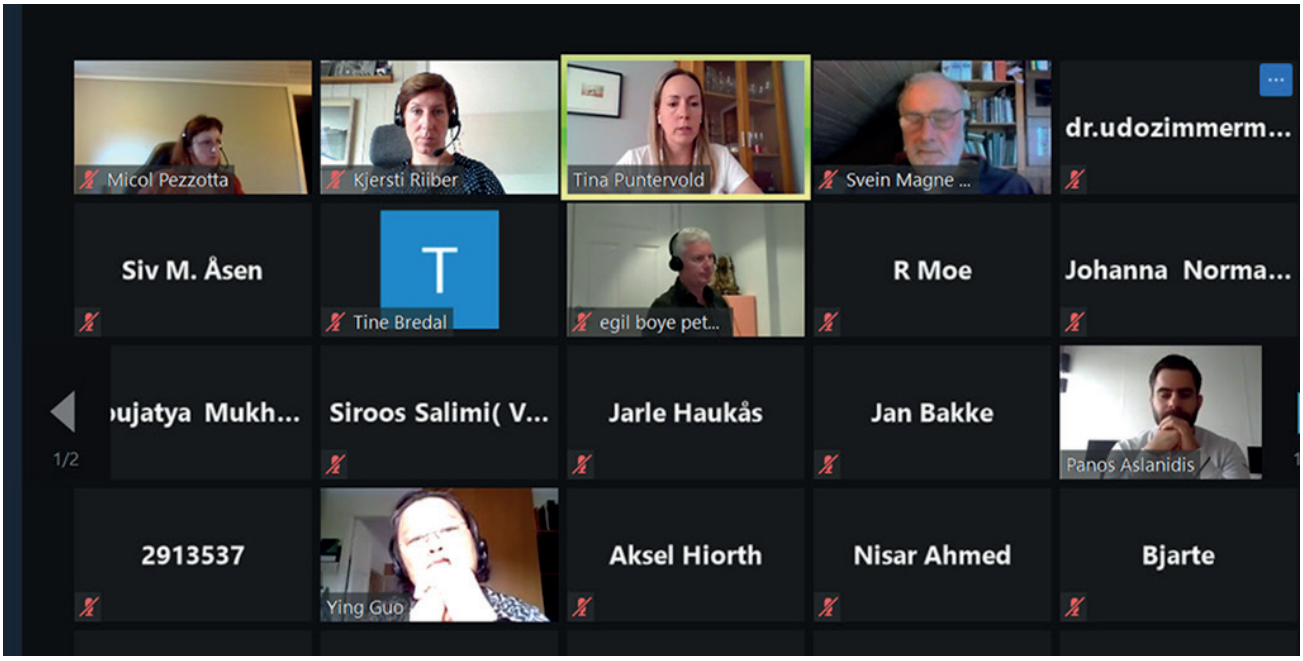
Within these categories, we have specified concrete deliverables from each project, tools that can contribute to environmental-friendly and cost-efficient methods for improved oil recovery. But to make sure we are progressing towards these deliverables, we have established "delivery forums". Each forum consists of representatives from the IOR Centre management team, project leaders, PhD students and postdocs, and of course representatives from our industry partners.

THE WAY FORWARD

The delivery forums will meet on a regular basis to make sure the research projects across tasks and themes are progressing in collaboration, to reach common goals with quality, and on schedule. The forums are also an arena for sharing our work.

At the first kick-off delivery forum (wettability and smart water EOR) we asked the participants for feedback on what topics to cover in future forum meetings. Field applications and use cases were among the suggestions.

Text: Kjersti Riiber



A common view for everyone working from home. Digital kick-off meetings for Delivery Forums were arranged 26-27 May. Screenshot

From top left Rolf Lorentzen (NORCE), Dario Grana (University of Wyoming), Geir Evensen (NORCE) and Jarle Haukås (Schlumberger).

Almost 60 participants participated in the two day-workshop with talks on ensemble-based 4D seismic history matching.

14-15 October, 2020, The National IOR Centre of Norway arranged a virtual workshop on ensemble-based 4D seismic history matching. As many as 60 participants from industry and academia logged in via Zoom to discuss the industry use, the research forefront, and the future needs of this topic.

The agenda included talks from Rolf Johan Lorentzen (NORCE), Dario Grana (University of Wyoming), Geir Evensen (NORCE) and Jarle Haukås (Schlumberger Research).

The workshop was arranged by NORCE and University of Stavanger.

Text: Kjersti Riiber

IOR CENTRE WORKSHOPS 2020

- **DELIVERY FORUM WEBINAR**
26-27 May (see page 22).

- **ENSEMBLE-BASED 4D SEISMIC HISTORY MATCHING**
14-15 October.

- **IORSIM**
10 December.

50 of the IOR Centre's researchers, project managers and PhD students were gathered at Sola Strand Hotel for a day of good talks, inspiration and socialization.

An important part of the agenda this day was to give the Centre researchers an introduction to the so-called "Deliverable Forums". The goal is to make a concrete list of deliverables for our industry partners. What will our partners gain after eight years of intensive research conducted at the IOR Centre. To achieve this list of deliverables within the first phase of the Centre's lifetime (till November 2021) we have to collaborate across research tasks and themes, and in close dialogue with our industry partners. Another part of the Centre gathering was to discuss the future of the IOR Centre – phase 2.

THE YOUNG VOICES

At a team gathering like this, you are bound to listen to the familiar voices of your old colleagues. To give the participants some new and inspiring input, #DenNyeOljen came to update us on the young people's view on the Norwegian oil and gas industry. #DenNyeOljen is an independent project organized by Norwegian Oil and Gas. Their mandate is to travel around the country to share their reflections on big issues like energy, technology and climate change.

To sum up; the first thing kids in Norway think of when they hear the word "oil" is pollution.

"This has changed in just one year. When we asked the same question back in 2018, pollution was mentioned only by a few. Now 1 of 3 associate the oil and gas industry with CO_2 emissions," Tuva Kvåle in #DenNyeOljen explained.

But the picture is more nuanced than that. A large part of today's young people realize that oil industry revenues are needed to develop new, green technology.

THE CENTRE - PHASE II

The Centre management is getting ready for phase II of The National IOR Centre of Norway. To get there, the management team asked for feedback from the researchers and students present at the gathering.

"I think the Centre needs to have a practical approach combined with academic freedom for the researchers," Tien Nguyen said. He is the newest PhD student at the Centre and got to meet his new colleagues for the first time this day.

"Regardless of how long the petroleum industry will last in Norway, IOR will be an important discipline in the rest of the world for years to come," PhD student Andre Morosov said.

The feedback from the researchers, PhD students and project managers is of great importance for the further work of planning the second phase of the IOR Centre.

Text and photos: Kjersti Riiber

Mario Silva and Sindre Hassfjell (IFE).

Henrik Hveding, Tuva Kvåle and Andreas Bakkehaug from #DenNyeOljen (the new oil).

Centre director Ying Guo.

From left research director Randi Valestrand, assistant director Tina Puntervold and director of field implementation Sissel Opsahl Viig.

Around 50 participants attended the IOR Centre gathering.

2020 was an extraordinary year. Most of us were working at home several weeks to fight against the spreading of the corona virus. No conferences, no social gatherings, and therefore a bit more time to write scientific articles.

Zoom, Teams, all those digital meetings will forever represent the feeling of 2020, the year the pandemic came into our lives. For those of us working with research and dissemination, an important arena was lost – the physical conferences. At the University of Stavanger the scientific staff spent much time facilitating for digital teaching. Some of us got more time on our hands, others had the most busy year ever. In 2020 the researchers at The National IOR Centre of Norway wrote a total of 27 scientific papers (see figure below), a very high number considering very few attended conferences.

DIGITAL PHD DEFENCE

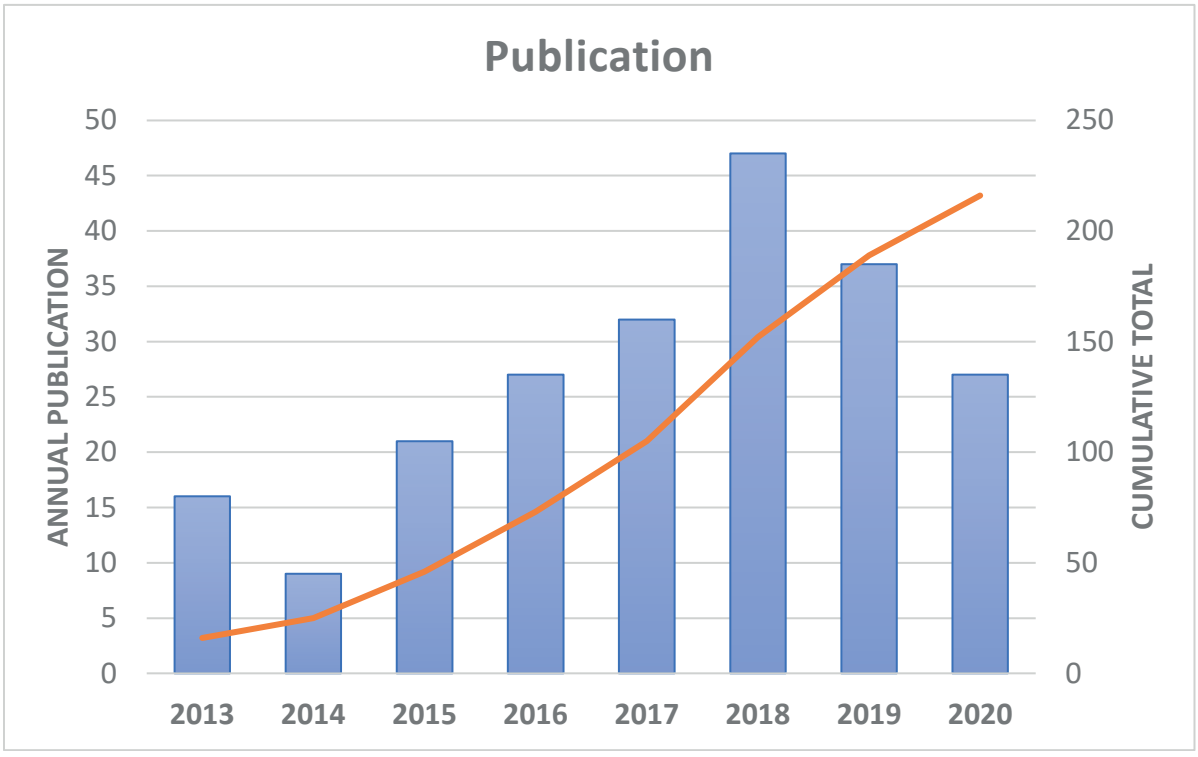
2020 also gave us the first digital PhD defence at The National IOR Centre of Norway. PhD candidate Jaspreet Singh Sachdeva defended his thesis from his flat in Bærum, watching his committee on the computer screen. Sachdeva defended his thesis in April, and since then we have had two more hybrid PhD defences; Dhruvit Berawala in October and Emanuela Iedidia Kallesten in December.

MODELING THE VIRUS SPREAD

For our researchers focusing on modeling, the virus outbreak gave possibilities. Professor Aksel Hiorth, the task leader for upscaling, together with colleague Roald Kommedal wrote a popular scientific article on mathematical models for outbreak of viruses like Covid-19.

«How can we know if various measures against infection have an effect? Is the cure tougher than the disease? And do we decide this from the gut feeling, or are there other ways to figure this out? These are complicated questions that are difficult to answer, and then there are doubts and fears. One way to help the brain is to formulate the problem in mathematical models. The official infection figures must be interpreted with a good model that considers data uncertainty and is consistent with data describing how the infection came to Norway.»

Text: Kjersti Riiber



Introducing the two newest PhD candidates at The National IOR Centre of Norway; Nisar Ahmed and Hoang Nguyen.

Nisar Ahmed is one of the PhD candidates in task 7, Field scale evaluation and history matching. He started his PhD work October 2019. His main supervisor is Wiktor Weibull (UiS).

OBJECTIVE

This research project (4D seismic frequency dependent AVO inversion to predict saturation-pressure changes) deals with the problem of seismic reservoir characterization and improved recovery. The objective is to develop an appropriate theoretical background and workflow, for including frequency dependence into the 4D (time-lapse) seismic AVO inversion and analysis to estimate viscoelastic properties, pressure and fluid saturation changes. Finally, the results will be compared with results obtained from conventional AVO inversion where frequency dependency is not included.

PATH FORWARD

- Applying the inversion code on real seismic data and analyzing the accuracy of results on real seismic data.
- Investigation of the effect of including frequency dependence on the ability to solve the inverse problem and look for optimal ways to optimize this solution.
- Publication of peer-reviewed research papers and collaboration with the research partners

Nisar Ahmed works on the project 4D seismic frequency dependent AVO inversion to predict saturation-pressure changes.

Hoang Nguyen is one of the PhD candidates in task 7, Field scale evaluation and history matching. He started his PhD work February 2020. His main supervisor is Nestor Cardozo (UiS).

OBJECTIVE

The research project Integrated reservoir and decision analysis of the Edvard Grieg Field, Utsira High, North Sea is a collaboration with Lundin Energy Norway. The objective is:

- Verifying the tectonic evolution and the conceptual depositional systems of the field
- Improving the reservoir characterization
- Model calibration and uncertainty analysis

PATH FORWARD

The project will deliver three aspects:

1. Structural and sequence stratigraphic reconstruction
2. Geological modeling and uncertainty evaluation
3. Dynamic simulation and production forecast

The candidate works to improve the understanding of uncertainties related to the static model, and also to mprove the quality of the dynamic model. By the end of the project Nguyen will deliver more reliable production forecast and propose an integrated workflow for reservoir characterization.

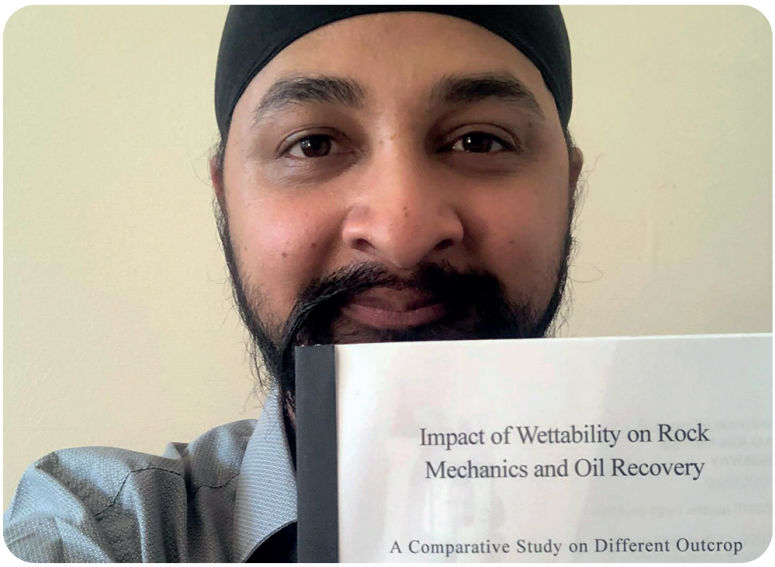
Hoang Nguyen works on the project Integrated reservoir and decision analysis of the Edvard Grieg Field, Utsira High, North Sea.

PhD Defences 2020

GRADUATED IOR CENTRE PHD CANDIDATES

Aojie Hong
Kun Guo
Laura Borromeo
Mona Wetrhus Minde
Oddbjørn Nødland
Remya Nair
Mohan Sharma
Samuel Erzuah
Shaghayegh Javadi
Tijana Voake
Jaspreet Singh Sachdeva
Dhruvit Berawala
Emanuela Kallesten

Tijana Voake defended her PhD thesis "Thermal properties of reservoir rocks, role of pore fluids, minerals and diagenesis. A comparative study of two differently indurated chalks" January 22nd. The purpose of the project has been to investigate how temperature variations in chalk reservoir induced by the injection of cold water and cross flow may affect the mechanical strength of chalk.



COMING UP:

Mario Lopes da Silva
Siv Marie Åsen
Eystein Opsahl
Bjarte Hetland
Anna Kvashchuk

PhD candidate at The National IOR Centre of Norway, Jaspreet Singh Sachdeva, defended his dissertation for the degree of PhD (philosophiae doctor) Monday 20 April, 2020. Jaspreet was actually at home in Bærum. The listeners followed the defence in their respective home offices. The defence was in two parts, a trial lecture titled "Does chalk behave like rocks or soils, and when? A constitutive model review". The defence had the title: «Impact of Wettability on Rock Mechanics and Oil Recovery».

Dhruvit Berawala defended his doctoral degree November 24th. The title of the dissertation is «Numerical Modeling of Gas Production and CO_2 Injection in Tight Shale Reservoirs for Enhanced Gas Recovery». In the background committee member Yu-Shu Wu.

Emanuela Kallesten defended her thesis December 16th. The title of the dissertation is Permeability evolution in chalk linked to stress and thermochemical aspects of North Sea reservoir conditions.

Photos: Kjersti Riiber

IOR 2020 webinar summed up

Due to the corona virus outbreak, we decided to cancel the IOR NORWAY 2020 conference & the 14th International Symposium on Wettability and its effect on Oil Recovery, as so many other events last spring. Instead we arranged a webinar in October. 55 people logged in to the IOR NORWAY webinar to listen to four of the speakers from the original conference programme. In the IOR NORWAY webinar, the participants got to hear interesting talks from Tove Francke (Norwegian Petroleum Directorate), Gunnar Lille (OG21), Øystein Espelid (Equinor) and Ann Muggeridge (Imperial College London).

We arranged for two discussion sessions in the programme. The speakers got many questions from the audience on topics like reservoir studies, pilots, CO_2 EOR and consequences of the COVID-19 pandemic.

Text: Kjersti Riiber

- Ann Muggeridge
  Imperial College London
  EOR Screening Including Technical, Operational, Environmental and Economic Factors Reveals Practical EOR Potential Offshore on the Norwegian Continental Shelf
- Tove Francke
  Norwegian Petroleum Directorate
  The challenging barrels
- Gunnar Hjelmtveit Lille
  OG21
  The key role of technology to obtain "close to zero" greenhouse gas emissions from the NCS in 2050 whilst maintaining profitability
- Øystein Espelid
  Equinor
  Equinor's updated climate amitions

The board of the Norwegian Chemical Society has awarded Kun Guo the prize for best doctorate in catalysis 2019. Photo: Marius Vervik

The board of the Norwegian Chemical Society has awarded Kun Guo the prize for best doctorate in catalysis 2019. Kun's PhD project was financially supported by the IOR Centre. The project focused on upgrading of heavy crude oil, which accounts for about 70 % of total world oil reserves.

«... Remarkable catalytic performance has been demonstrated, highlighting the potential of these catalytic systems. Kun's achievements also entitled him the 2018 Chinese Government Award for Outstanding Self-Financed Students Abroad,» according to the magazine Chemistry.

Guo got the prize October 2020.

Geir Evensen won NPD's IOR award 2020

The Norwegian Petroleum Directorate's IOR award goes to production licenses, companies, projects or individuals who are expected to create added value on the Norwegian Continental Shelf through innovative work for improved recovery. This year's prize was the 16th since the first award was handed out in 1998.

The winner of the IOR award 2020 was researcher Geir Evensen from NORCE. The jury found that Evensen has made significant contributions over a number of years toward the development of modeling methods based on the ensemble approach. This technology is used extensively among the oil and gas companies on the Norwegian Continental Shelf.

The research group in task 7 at The National IOR Centre of Norway works with field scale evaluation and history matching. They have played an important part in the development of modelling methods based on the ensemble approach. The IOR Centre researchers have also been important collaborators in Evensen's work.

«The method you have developed leads to a better basis for making decisions, and thereby improved value creation», Director General Ingrid Sølvberg in NPD said when she presented the award.

Geir Evensen is awarded NPD's IOR Award.
Photo: Norwegian Petroleum Directorate

PhD student of the year

PhD student at The National IOR Centre of Norway, Dhruvit Berawala (picture), was honored with the award «PhD student of the year» at the SPE (Society of Petroleum Engineers) gala night. This is SPE Stavanger's prize for students with excellent academic performance at University of Stavanger. Berawala did his PhD project on the subject «Numerical Modeling of Gas Production and CO_2 Injection in Tight Shale Reservoirs for Enhanced Gas Recovery». He defended his thesis October 2020 (see page 29).

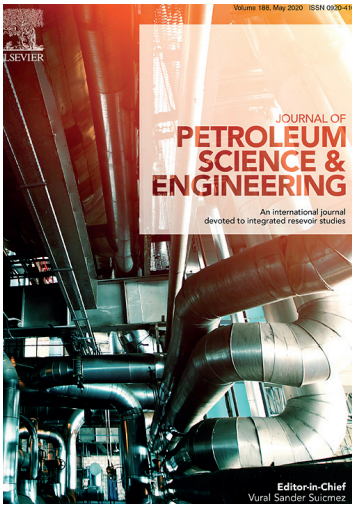
«I am truly honored to receive this award from SPE Stavanger for recognizing all the hard work done over the past three years. A big credit goes to my supervisor Dr. Pål Andersen, The National IOR Centre of Norway and the Department of Energy and Petroleum Engineering, UiS for their immense support and guidance,» Berawala said after receiving the award.

Berawala is now working as Senior Reservoir Engineer in Equinor.

These are the task leaders' selected papers for 2020.

TASK 1

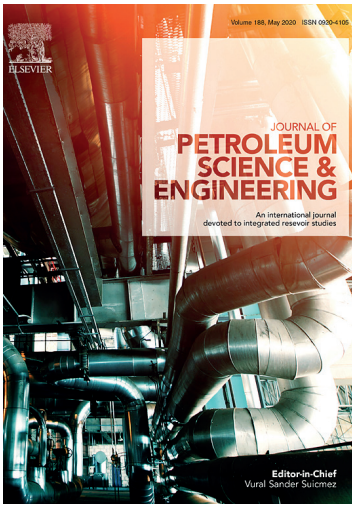
"Core wettability reproduction: A new solvent cleaning and core restoration strategy for chalk cores"
Ivan Pinerez, Tina Puntervold, Skule Strand, Paul Hopkins, Panagiotis Aslanidis, Hae Sol Yang, Magnus Sundby Kinn



To improve oil recovery by the use of water-based methods relying on wettability alteration of the reservoir to more water-wet conditions, it is important to have a good understanding of the initial reservoir wettability. If the reservoir initially is very water-wet, then the potential of improving oil recovery from the field by methods such as Smart Water flooding or low salinity waterflooding, is limited. In laboratory work, core cleaning and restoration methods are used to establish initial wettability, which should resemble the initial wettability of the reservoir. Because of limited amounts of representative core material, especially from reservoirs, cores may have to be reused in laboratory experiments. Being able to reproduce the initial wettability in multiple core restorations and laboratory tests is crucial for comparing results and producing reliable experimental data. In this paper, the amount of crude oil exposure during the restoration process in outcrop chalk and its effect on initial wettability has been investigated. The results from this work show that increased crude oil exposure is reducing the water wetness of the cores, and that reproduction of wettability was achieved by limiting the crude oil amount to one pore volume after a mild core cleaning procedure. This work is a step closer to reproducing representative wettability in core plugs.
https://doi.org/10.1016/j.petrol.2020.107654

TASK 2

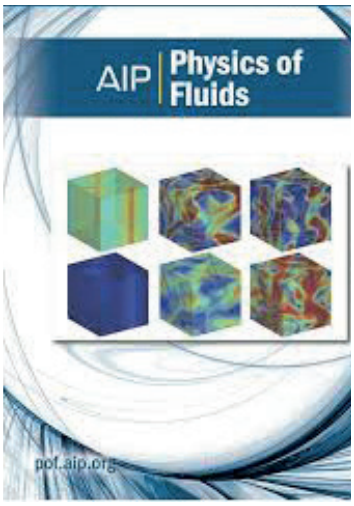
"Validation study of water weakening research from outcrop chalks performed on Eldfisk reservoir cores"
Emanuela I.Kallesten, Yosra Cherif, Merete V. Madland, Reidar I. Korsnes, Edvard Omdal, Pål Østebø Andersen, Udo Zimmermann



The PhD work by Ema Kallesten resulted in various international peer-reviewed articles. A stand-out is surely the first thorough publication about tested samples from an actual reservoir at the NCS at Eldfisk. This is major landmark for industry and the academic context because it allows for the first time to verify our decade-long research on on-shore chalk. This will be followed by the first in-depth contribution on the composition of off-shore chalk from reservoirs and non-reservoirs (Kallesten et al. in press) and complete the efforts to structure chalk research within the field of EOR. The results are extremely important for all researcher and interested parties related to rock-fluid interaction in porous media. (The article has been published in 2020 on-line.)
https://doi.org/10.1016/j.petrol.2020.108164

TASK 3

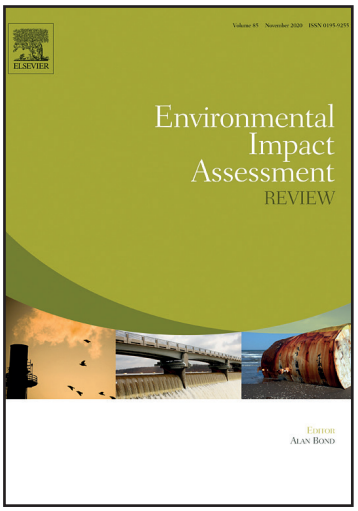
"Start-up and cessation of steady shear and extensional flows: Exact analytical solutions for the affine linear Phan-Thien–Tanner fluid model"
D. Shogin



This paper describes analytical results for a network model of polymeric fluids called the Phan–Thien—Tanner model, named after Nhan Phan–Thien and Roger Tanner who proposed the new constitutive equation in the late 1970s. The steady-flow rheology of the fluid is derived and exact analytical solutions are obtained and

is presented in a more accessible form than found in the literature which makes for easier applications in experiments and numerical modelling. The analytical equations for transient behaviour is also derived for the start-up flow and halting of the flow. Both of these regimes show strong memory effects which is not captured in the more standard generalized viscosity models. In addition to being an important results in its own right,t as there exist few analytical results for unsteady non-Newtonian flow, it is also highly useful for the numerical models being developed in the pore scale task.
https://doi.org/10.1063/5.0017326

TASK 4



"An environmental risk assessment framework for enhanced oil recovery solutions from offshore oil and gas industry"
Mehul Vora, Steinar Sanni, Roger Flage

Environmental risk assessments are necessary to understand the risk associated with enhanced oil recovery (EOR) solutions and to provide decision support for choosing the best technology and implementing risk-reducing measures. This study presents a review of potentially relevant environmental/ecological risk assessment (ERA) guidelines and, based on this review, proposes an initial suggestion of an ERA framework for understanding the environmental impacts from EOR solutions. We first shortlist the important elements necessary for conducting an ERA of EOR solutions from the selected guidelines. These elements are then used to build the suggested ERA framework for produced water discharges, drilling discharges and emissions to air from EOR solutions, which is the primary objective of the present study. Furthermore, the emphasis is placed on identifying the knowledge gaps that exist for conducting ERA of EOR processes. In order to link the framework with the current best environmental practices, a review of environmental policies applicable to the marine environment around the European Union (EU) was conducted. Finally, some major challenges in the application of ERA methods for novel EOR technologies, i.e. uncertainties in the ERA due to lack of data and aggregation of risk from different environmental impacts, are discussed in detail. The frameworks suggested in this study should be possible to use by relevant stakeholders to assess environmental risk from enhanced oil recovery solutions.
https://doi.org/10.1016/j.eiar.2020.106512

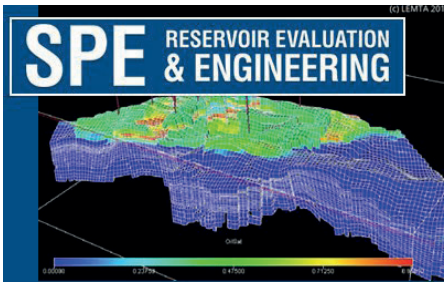
TASK 5

"Determination of phase-partitioning tracer candidates in production waters from oilfields based on solid-phase microextraction followed by gas chromatography-tandem mass spectrometry"
Mario Silva, Tor Bjørnstad

We report the development of an analytical method consisting of a sequential direct-immersion/headspace solid-phase microextraction followed by gas-phase chromatography and tandem mass spectrometry for simultaneous analysis of 4-chlorobenzyl alcohol, 2,6-dichlorobenzyl alcohol, 4-methoxybenzyl alcohol, 3,4-dimethoxybenzyl alcohol, pyridine, and 2,3-dimethylpyrazine in oilfield production waters. These compounds are under evaluation for use as phase-partitioning tracers in oil reservoirs. To the best of our knowledge, this is the first time SPME has been applied to the analysis of these compounds in production waters, or any other type of matrix where the compounds targeted are the base for a technical application. Relevant extraction parameters, such as the adsorbent phase of the fiber, direct immersion or headspace, addition of salt, temperature and time of extraction were investigated. The limits of quantification (LOQ), linearity, precision and accuracy of the method were evaluated. Analyses of the tracer compounds and recovery studies were also performed on production waters from 8 different oilfields of the Norwegian continental shelf. LOQs between 0.080 and 0.35 μg L−1 were obtained. The recovery yields of the method were consistently higher than 85% and RSDs less than 13%. None of the tracer compounds was found in the real samples processed, which is consistent with one of the requirements for an artificial tracer in an oilfield: absence or constant and low background in the traced fluid. The performance of the method developed, combined with its easiness to automate, introduce a new, accurate and cost-efficient technique to process the hundreds of samples required by an inter-well tracer test.
https://doi.org/10.1016/j.chroma.2020.461508

Selected Papers

TASK 6



"Evaluation of Multi-component Adsorption Kinetics for CO2 Enhanced Gas Recovery from Tight Shales"

Dhruvit Satishchandra Berawala, Pål Østebø Andersen

Only 3-10 % of gas from tight shale is recovered economically through natural depletion, demonstrating a significant potential for enhanced shale gas recovery (ESGR). Experimental studies have demonstrated that shale kerogen/organic matter has higher affinity for CO2 than methane, CH4, which opens possibilities for carbon storage and new production strategies. This paper presents a new multicomponent adsorption isotherm which is coupled with a flow model for evaluation of injection-production scenarios. The isotherm is based on the assumption that different gas species compete for adsorbing on a limited specific surface area. Rather than assuming a capacity of a fixed number of sites or moles this finite surface area is filled with species taking different amount of space per mole. The final form is a generalized multicomponent Langmuir isotherm. The isotherm is first applied in static examples to calculate gas in place reserves, recovery factors and enhanced gas recovery potential based on contributions from free gas and adsorbed gas components. The isotherm is further coupled with a dynamic flow model with application to CO2-CH4 substitution for CO2-ESGR, assuming only gas phase exists in the system. We study the feasibility and effectiveness of CO2 injection in huff-and-puff settings. The injected CO2 displaces, but also mixes with the in situ CH4. Diffusion allows the CO2 to travel further into the matrix while keeping CH4 accessible to the well. Surface substitution further reduces the CO2 content and increases the CH4 content in the gas mixture that is produced to the well. A result of the isotherm is that adsorption of CO2 with resulting desorption of CH4 will lead to a reduction in total pressure if the CO2 content in the gas composition is increased. That is in itself an important drive mechanism since the pressure gradient driving fluid flow is maintained (pressure buildup is avoided). This is because CO2 takes ~24 times less space per mol than CH4.

https://doi.org/10.2118/195536-PA

TASK 7

"Natural fault and fracture network characterization for the southern Ekofisk field: A case study integrating seismic attribute analysis with image log interpretation"

Quinten Boersma, Wiebke Athmer, Martin Haege, Marie Etchebesc, Jarle Haukås, Giovanni Bertottia

Production from the Ekofisk Chalk Field in the North Sea is believed to be significantly influenced by the presence of a connected fault and fracture network. In the current study, we create a 3D seismic discontinuity cube which is representative of this network within the southern part of the Ekofisk Field. This is done using a multiscale workflow which integrates seismic fault and fracture detection with borehole image log interpretation from three horizontal well sections. The results show that faults and fractures are prevalent in the Ekofisk Formations. Within the study area, faults are mainly organised in three orientations: 1) WNW-ESE, 2) NNE-SSW and 3) NNW-SSE. Smaller E-W striking faults are also observed. The interpreted fractures show a similar pattern and are organized in four orientation groups: NW-SE, WNW-ESE, ENE-WSW and NE-SW. The analysis of seismic discontinuity data (i.e. faults and fractures detectable on seismic) indicates that most small-scale discontinuities occur in proximity to large faults, and that the Lower Ekofisk Formation is characterized by more widespread – and a higher intensity of small-scale seismic discontinuities. It is also demonstrated that along each studied well section, the extracted seismic discontinuities show a qualitative correlation with the image log interpretation. This correlation suggests that the 3D seismic discontinuity cube can serve as a proxy for the fault and fracture network in the southern part of the Ekofisk Chalk Field. Following from our key findings, we conclude that the presented workflow and results could provide a starting point for future studies assessing the impact of natural fractures in the Ekofisk – and other complex reservoirs.

https://doi.org/10.1016/j.jsg.2020.104197

Media Contributions 2020

IOR-prisvinner Geir Evensen mottar gaver fra Ingrid Sølvberg.

01.09.2020 For 16. gang delte Oljedirektoratet ut en
økt utvinning. Denne gang gikk IOR-prisen til forsker
Evensen ved forskningsinstituttet NORCE.

Olje- og e
Reiso fra
Rappor
fra Olje
effekte
rettet r

Avanserte metoder for reservoarforståelse har gitt økt utvinning

Avanserte metoder for reservoarkarakterisering har bidratt sterkt til økt oljeproduksjon. Forskningen og utviklingen av metodene er hovedsakelig utført av forskere ved NORCE.

Sist oppdatert: 21. feb. 2020
Publisert 7. feb. 2020

Veronica Helle
Rådgiver kommunikasjon

KJEMI 5 2020

Oljeadsorpsjon i reservoaret

DOKTORGRAD: Samuel Erzuah (34) har avlagt doktorgrad ved Universitetet i Stavanger om korleis olje bind seg til steinoverflata i oljereservoar.
Fukta i stein- og mineraloverflater i oljereservoara avhenger av såkalla adsorpsjon av polare oljekomponentar. Adsorpsjon er ein prosess som skjer når ein gass eller væske blir bunden til overflata av eit fast stoff eller væske. Erzuah har studert fuktvilkåra i reservoaret og korleis dei blir påverka av interaksjonar mellom råolje, vatn og stein.

Første fase av studiet var eksperimentelt. I neste fase vart resultata modellert. Under modelleringa vart mengde oljeadsorpsjon påvist, og òg adsorpsjonsmekanismane.

Dei eksperimentelle teknikkane som vart brukte var flotasjonstest, oljeadsorpsjon med mikrovekt (Quartz Crystal Microbalance with Dissipation, QCM-D) og kontaktvinkelmåling

ge overflateeigenskapar i laboratoriet. Fukta i oljereservoara styrar både fluidfordelinga og strømmingseigenskapane. I olje- og gassindustrien kan SCM brukast til å optimalisera komposisjonen av injeksjonsvatnet som blir brukt i oljereservoara for dermed å auka oljeproduksjonen.

Forskinga vart finansiert av Forskingsrådet og Det nasjonale IOR-senteret sine ni industripartnarar.

Kandidaten

- Samuel Erzuah er 34 år og frå Kumasi i Ghana. Fagområdet hans er bore- og brønnteknikk og doktorgradsarbeidet vart utført ved Det nasjo-

Kronikk

Imagine The Potential

Nylig fikk vi informasjonen om at Equinor vurderer å øke utvinningen på Statfjord A plattformen samt øke den totale verdiskapningen fra feltet nok en gang. Statfjord produsert verdier for svimlende 1500 milliardar norske kroner siden oppstarten i

29.januar 2020 Av Håkon Skretting, direktør Norwegian Energy Partners

De planene som lå til grunn for Statfjord-utbyggingen var at feltet skulle leve i 20 år fremdeles kan vi se for oss at Statfjord A vil bidra med 4.000 til 5.000 årsverk og be er bare et eksempel på hva industrien har oppnådd på sokkelen og som er med og

Det er symptomatisk at en slik positiv informasjon ikke får mer oppmerksomhet i noen få aviser og skuldertrekning fra de fleste av de som gidder å lese den er nest vane. Som om det kommer av seg selv. Men det gjør det ikke. Oljevirksomheten t konservativ og lite innovativ. Det er absolutt feil. Da Statfjord-feltet ble bygget, var utviklet. En boret rett ned og eventuelt litt på skrå for å nå ut til de forskjellige dele

Det vakte oppsikt da en forsker i mars anbefalte full
Professor Aksel Hiorth og førsteamanuensis Roald
Universitetet i Stavanger, var ikke enig. De diskuter
og anbefaler:

9.

Pris for beste doktorgrad i katalyse til Kun Guo

Styret i Norsk Kjemisk Selskap – Faggruppe for katalyse har tildelt faggruppens pris for beste doktorgrad i katalyse 2019 til Kun Guo. Guo tok doktorgraden ved Universitetet i Stavanger med Zhixin Yu som hovedveileder.

Kun's PhD project is financially supported by the National IOR Centre of Norway. This project focuses on upgrading of heavy crude oil, which accounts for ca. 70% of total world oil reserves. Heavy or extra heavy oils are highly viscous and uneasy to flow under normal reservoir conditions. Relative to water that has a viscosity of ~1 centipoise (cP) at room temperature, heavy oil's viscosity is normally larger than 100 cP. Thereby, conventional flooding methods are insufficient and in-situ heavy oil upgrading inside the reservoir is required prior to the oil recovery. Equally important is the ex situ upgrading of recovered oil prior to the commercial usage. Such upgrading processes involve a series of hydrotreating reactions with the ultimate goal of viscosity reduction and quality enhancement.

Rational design and synthesis of high-performance catalysts are of vital importance for the in-situ and ex-situ catalytic upgrading of heavy crude oil. To this end, Kun's PhD thesis reports the synthesis and application of monodispersed nickel and cobalt nanoparticles (NPs), common carbon materials (i.e., carbon nanotubes, graphene and carbon black), and carbon supported nickel as catalysts for the in-situ upgrading, together with thiospinel ($NiCo_2S_4$) NPs and molybdenum disulfide (MoS_2)-based monolayers as catalysts for the ex-situ upgrading. These catalysts are evaluated using either model compounds, such as thiophene and pyridine, or heavy crude oil. In each case, remarkable catalytic performance has been demonstrated, highlighting the potential of these catalytic systems. Kun's achievements also entitled him the 2018 Chinese Government Award for Outstanding Self-Financed Students Abroad.

Kun Guo graduated with a B.Eng. in Materials Science & Engineering from Huazhong University of Science & Technology in 2011, a M.Eng. in Chemical Engineering from Shanghai Advanced Research Institute in 2014, and Ph.D. in Petroleum Engineering from University of Stavanger in 2018. He did a post doctor research at Manchester Uniserity, UK during 2018-2019 and is currently Associate Professor at School of Chemistry and Chemical Engineering in Shaoxing University, China. ●

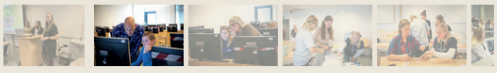
Kun Guo. Foto: Kjersti Håheim/UiS.

Det er helt avgjørende at så mye data som mulig blir samlet inn og gjort tilgjengelig, og at

Korona, ebola og zombie

DEBATT

Selma Thu får hjelp av Aksel Hiorth i programmeringsworkshopen. Tema: Hvor fort spres et zombie-utbrudd?



Det er Realfagsrekruttering som står bak Girls Day in Tech. Tirsdag var første gang Universitetet i Stavanger arrangerte dagen, hvor alt handler om jenter og teknologi.

44 jenter fra Vågen og Hetland videregående skoler deltok. I løpet av dagen fikk de høre inspirasjonsforedrag, de fikk møte rollemodeller som har valgt teknologiutdanning, og de fikk prøve egne evner i tre ulike workshops.

e book "En åpen linje"; poetry by petroleum researcher at IFE Jan

petroleum research to writing poetry might be shorter
Jan Sagen, newly retired petroleum researcher at IFE,
his first book, "En åpen linje". This could be translated
", but has little to do with open telephone lines or
s in television programmes.

lly played on three things: 1) An open line of poetry, 2)
mmunication to our surroundings and people around
line in human behavior," Jan Sagen says.

OPERATING COSTS 2020
(All numbers in 1000)

Payroll expenses	24 327
Procurement of R&D services	19 636
R&D services – in kind	4 019
International R&D services – in kind	350
Other operating expenses	2 296
Total operating expenses	50 628
Operating profit	0

PROJECT COSTS

Personnel and indirect costs	
UiS	19 955
User partners – in kind	2 982
R&D services	19 630
Equipment	1 037
Other operating expenses	246
Sum	43 850

Operating profit	6778
Salary	4728
Other expenses	2050

Comments

- Total positive operating profit of MNOK 6.7 was transfer to 2021 budget;
- of the profit of 6.7 MNOK, kNOK 4728 of the operating profit was allocated to man-power costs at UiS, but not spent due to project delay caused by Covid-19
- of the profit of 6.7 MNOK, 2.05 MNOK was allocated to operating cost for travels and conferences but not spent due to Covid-19

Who are we?

Management Team & Administration


Ying Guo
UiS/NORCE
Centre director


Tina Puntervold
UiS, Assistant director /
Leader Theme 1


Randi Valestrand, NORCE
Research director /
Leader Theme 2


Aksel Hiorth, UiS/NORCE
Director of Academia &
Research


Sissel Opsahl Viig
IFE, Director of Field
Implementation


Sven M. Skjæveland
UiS
Advisor


Micol Pezzotta, UiS
Administrative
coordinator


Kjersti Riiber, UiS
Communications advisor


Yasar Deniz Cam, UiS
Economy advisor

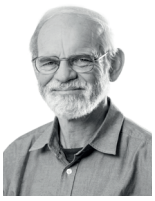
Task Leaders


Arne Stavland, NORCE
Task 1 / Project manager


Udo Zimmermann, UiS
Task 2 / Project manager


Espen Jettestuen, NORCE
Task 3 / Project manager


Aksel Hiorth, UiS/NORCE
Task 4 / Project manager


Tor Bjørnstad, IFE
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Ove Sævareid, NORCE
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Geir Nævdal, NORCE
Task 7 / Project manager

PhD Students


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Tijana Voake


Irene Ringen


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Panagiotis Aslanidis


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Eystein Opsahl


Siv Marie Åsen


Mehul Vora


Mario Silva


Arun Selvam


Dhruvit Berawala


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Yiteng Zhang


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Micheal Oguntola


Nisar Ahmed


Hoang Nguyen

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Oddbjørn Nødland

Juan Michael Sargado

Trine S. Mykkeltvedt

Birane Kane

Kjersti Eikrem

Runar Berge

Rouholah Ahmadi

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Åsen, Siv Marie.
Polymer Rheology at Micro- and Darcy Scale. Delivery Forum Kick-Off; 2020-05-26 - 2020-05-27
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The National IOR Centre of Norway

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With funding from
The Research Council of Norway