Annual Report 2018
Danish Hydrocarbon Research and Technology Centre (DHRTC)

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Front: 3D image of the pore system (the rock matrix has been made invisible) of a Danian chalk sample from the North Sea. The image is reconstructed from nano-CT collected at the SPring-8 synchrotron in Japan with a voxel size of 40 nm.

We have a clear line of sight
Four DHRTC projects have achieved the aim of bringing technology innovations to Technology Readiness Level 3, from where our industrial partners have the option to implement them. Morten Willaing Jeppesen, Centre Director, DHRTC, looks forward to 2019 being a year of continued progress.

Radial Jet Drilling at a cross road
Radial Jet Drilling technology is known to enhance oil and gas production onshore. DHRTC research shows, that it can also potentially increase production in the Danish North Sea, although more operational development is needed.

DHRTC overview
Our year in numbers.

DHRTC is successfully pursuing its goals
Rasmus Larsen, Provost at the Technical University of Denmark, finds that DHRTC is successfully pursuing its goals. A new scientific framework will lead to innovations in the field of digitalization and minimization of the environmental footprint of industry operations.

AlarmTracker ready for offshore testing
The AlarmTracker is a new solution helping operators make informed decisions in abnormal situations. In the first quarter of 2019, the AlarmTracker was installed for offshore testing at the Judy and Dan platforms.

DHRTC has come a long way and can be proud
In March 2018, DHRTC welcomed a new industrial partner, when the French multinational Total took over Maersk Oil’s activities in the Danish North Sea. Read an interview with Troels Albrechtsen, Vice President Copenhagen Offshore Product Line at Total.
Innovative researchers have no expiry date

Although Jørgen Gross-Petersen has retired three times, his mind is still full of innovative ideas for the oil and gas industry.

Get an introduction to some of the projects in our pipeline.

By loading existing seismic datasets into state-of-the-art seismic interpretation software, PhD Florian Smit has succeeded in exposing the buried sea floor of the hydrocarbon-bearing Chalk Group in the North Sea, like ‘Google Earth of the subsurface’. The aim is to enhance the prediction of reservoir quality.

When DHRTC hosts events and workshops, the purpose is to connect the right academic competencies to the right technical challenges. Overview of 2018 knowledge sharing events.

Chalk has a very low permeability. Only in fractures, can oil flow more easily. But where are these fractures, how many are there, and what is their orientation? New fracture models that simulate the growth of the fracture network through geological time may give an answer.

When you open a tap after the water supply has been disconnected, it often sputters and sprays completely uncontrollably due to air pockets in the water. Something similar takes place regularly in the separator, where production fluids are separated into oil, gas and water. A Radical Innovation Sprint project has developed an innovative solution on how to deal with this problem.

Four years ago, the DHRTC-administration began activities in an empty building with no comparable network-based research centre to emulate. Today, four hundred contracts have been produced, and 50 financial controllers work together across institutional borders to ensure that researchers can run their projects efficiently.

Every second year, The Danish Hydrocarbon Research and Technology Centre is contractually obliged to provide an evaluation. The centre has good reason to be pleased with the 2016-2018 ‘grades’.

Let’s meet and share knowledge

DHRTC from a scientific perspective

How to operate with excellence

New models can predict fracture patterns in chalk

Infusion of ‘young blood’

Existing vibration measurements may alleviate slugs
In 2019, the Danish Hydrocarbon Research and Technology Centre (DHRTC) will be half-way through its scheduled first 10 years of operation. The idea of the founders was that five research institutions should unite with industry, and with the backing of ten years funding have the right conditions to establish the centre’s raison d’être. Now, almost five years underway, how are we doing?

A recent external evaluation of the centre shows that we have come far, although, as to be expected from a half-way assessment, we still have some way to go (page 25). We are optimistic, and thanks to the support from our partners and stakeholders, we have a clear line of sight to complete the first ten years in a successful and forward-looking way.

DHRTC’s raison d’être is to deliver innovative solutions based on substantial and interdisciplinary research, and to develop talented employees for research institutions and the oil and gas sector.

Almost half-way, we are proud that the DHRTC researchers already are delivering excellent academic results. The publication record shows at least 49 publications. Almost 60 PhD students are involved with the centre, and the first two PhD defences have been delivered with many more to come. Thanks to openminded collaboration between the scientific partners, our technology application advisors and programme managers we have succeeded in defining six research programmes that are feeding well into the purpose of the centre: to perform applied research meeting urgent and important needs of the Danish Underground Consortium.

Four DHRTC projects have achieved the aim of bringing technology innovations to Technology Readiness Level 3, from where our industrial partners have the option to implement them. The AlarmTracker is a great example. The system is now being live tested, as you can learn more about on page 10.

Five years after we started from scratch, we have 250 people participating actively in the network, we have a strong administrative support platform (page 33), and we have three ideas considered for patents in our Radical Innovation Sprint Programme (page 30).

We build on trust, and we have begun a promising and trustful collaboration with our new industrial partner, Total, who took over Maersk Oil’s activities in the North Sea in 2018. Twice, already, we have been welcomed by Total’s R&D team in Pau, France. We now have experts from Total involved in a handful of projects, and we are happy to welcome Yves Guenard, Senior Manager Innovation Technology, Total, to our Steering Committee, as well as Hans Nørgaard Hansen, Head of Department at DTU Mechanical Engineering.

So I look forward to 2019 being a year of continued progress of our six research programmes as well as a year of opening up new chapters of the DHRTC story.
The Danish Hydrocarbon Research and Technology Centre is now four years into the ten year plan to find technological solutions for improving oil and gas production from the current infrastructure in the Danish North Sea. In this fourth year there is a series of accomplishments and events that I find are worth mentioning.

After taking the lead in building the organization of the centre Bo Cerup-Simonsen stepped down as director and returned to the shipping business in which he worked before joining DHRTC. Bo has skilfully headed the building of capacity at the centre from zero to a powerful organization at the interface between applied research and application. Moreover, Bo has eloquently addressed the necessity of conducting research into improved utilization of Danish underground resources, so that Denmark has the energy required to ensure growth and welfare in the transitional period until the fossil-free society becomes a reality.

Morten Willaing Jeppesen was appointed new DHRTC director. Given his previous long career with Maersk Oil & Gas and a year as Programme Director in DHRTC Morten is the ideal successor for the centre to fulfil its strategy.

DHRTC has in the past year also experienced a major result in spinning off the AlarmTracker project. The AlarmTracker project is a result of an early focus on digitalization as a game changer (page 10). I am quite certain that we will see more innovations coming out of the many projects that have been initiated.

Finally, I would like to emphasize the proposed new scientific framework that will formalize as a centre focus the minimization of environmental footprint of operations. It also includes digitalization and preparations for abandonment. Here also lie promising opportunities for DHRTC.

In conclusion, I find that the DHRTC is successfully pursuing its goals and its strategy and look forward to seeing more innovation and technology transfer from the centre.
2018 – Our year in numbers

- 320 MIO DKK: Total invested 2014-2018
- 250+: People associated with DHRTC
- 40+: Senior researchers/associated professors/professors engaged
- 409 proposals received
- 151 have been approved
- 60 ongoing PhDs
- 18+ nationalities
- 24 prototypes
- 7 projects considered for patenting
2018 has been an effective year. In 2019, the centre will concentrate on developing new research programmes and moving research and innovation closer to application.
Troels Albrechtsen was one of the founding fathers of DHRTC. As a representative of Maersk Oil, now Total, he and the partners in the Danish Underground Consortium (DUC) had a vision of bringing together five research institutions in order to create new and innovative solutions to the challenge of extracting the remaining oil and gas in the North Sea.

DHRTC has come a long way and can be proud

BY MARIANNE BOM

Now, almost half way into the scheduled timeframe of ten years, Troels Albrechtsen gives his views on the past and the future of DHRTC. After Total took over Maersk Oil in 2018, he became Vice President Copenhagen Offshore Product Line at Total.

What are the main accomplishments of the centre so far?

“It was a major accomplishment just to bring together the institutions within this framework. That was an innovation in our sector, and a first goal that the centre has fulfilled nicely. There were obstacles on the way but we overcame them and achieved a broad involvement that is evident from the publication list. Another accomplishment is the definition of the research programmes themselves, which are designed to answer the challenge of how to get more oil out of the ground, economically. Also, the centre has successfully adapted the programmes in response to the changing conditions brought about by the drop in oil price. There are already many good examples of specific deliverables from the program such as the 4D Maintenance Project and the AlarmTracker. We have come a long way and can be proud of what we have achieved so far.”

What are your expectations for the centre for the future?

“It is an important issue for the short term to follow up the scientific framework and the revision made in 2018. We added new elements; and decided to focus more on the environmental aspects of the oil and gas industry. Another issue is how to bring the centre’s results to fruition. Through the engagement of Total E&P in Esbjerg, and the wider industry we shall build prototypes and bring innovations to bear on the implementation and use of specific deliverables. It is important for the future to show a positive impact on activities in the North Sea. It is also important to participate in the debate on climate change. We know that oil
and gas will be used for a period of time. If we do not produce it, someone else will. So let us produce it in a safe and sound way.

What are your expectations for the future development of the interaction between Total and research and development in the centre?

“The first key to success is to continue to make the best use of knowledge among the five research institutions and to see everybody cooperating. The second is to engage with the service industry and create solutions that we can use in the North Sea, and to have researchers engage in the activities in the field of Total and other operators. This will happen through some of the technical committees; furthermore we have added a seat for Total in the Steering Committee to facilitate this development. I am not worried for the future. Total has taken over the activities in the North Sea with a real ambition to continue to develop them. The revision of DHRTC’s scientific framework was endorsed by the new owner, and Total is committed to bringing its technical abilities into the centre. In the longer term we should prepare for setting up a potential extension of DHRTC beyond the original 10 year time frame.”

“We have come a long way,” says Troels Albrechtsen, Vice President Copenhagen Offshore Product Line. “In the longer term we should prepare for setting up a potential extension of DHRTC beyond the original 10 year time frame.”

Photo: OGD
On a daily basis, the operators of an oil platform frequently need to analyse and decide on a response to an alarm, often without knowing the root cause. The AlarmTracker is a new solution based on DHRTC funded research helping operators make informed decisions in abnormal situations. In the first quarter of 2019, the AlarmTracker was installed for offshore testing at the Judy and Dan platforms.

The AlarmTracker is likely to be one of DHRTC’s first tangible deliveries to the oil and gas industry, and expectations for the new operator decision support system are high.

Eldor Technology, a Norwegian start-up company deeply involved in the development, predicts a possible five percent increase of oil production once the AlarmTracker is installed across the entire production system and integrated into a control and safety system on a platform. Furthermore, the AlarmTracker is expected to reduce the environmental footprint as well as the risk of safety incidents, since the solution will lead to better control of the complex production systems.
Later, the system will also provide an advice on action to be taken as decision support to the operators.

On the Judy Platform the scope of the test was the gas separation treatment and compression. In March 2019, further testing is to follow on the water interjection systems at Total’s Dan Platform. The main purpose in both cases being to test the functionality of the core software and the communication towards the operators.

A collaboration based on trust

“As to be expected from the first real environment tests there are some adjustments to be made in the software. As planned, the researchers at DTU Electrical Engineering will continue to participate in the development for some time to come,” says Erik Bek-Pedersen.

The core of the software solution is now considered to be at Technology Readiness Level 3, corresponding to a tested prototype, which is generally the aim for the DHRTC-projects. Erik Bek-Pedersen wants to express his gratitude to the people involved and specifically to the industry for their cooperation:

“To the researchers it has been of extreme importance that the industry has opened up access to the systems on the platform. We are grateful for the trust that ConocoPhillips and Total is showing us. We would never be able to do research and development of this high calibre without their collaboration,” says Erik Bek-Pedersen.

In early 2019, the AlarmTracker performed its first real environment test at the ConocoPhillips’ Judy Platform in the North Sea.

First tests were successful

“It is a major achievement that we now have the AlarmTracker installed on the Judy Platform. We are running tests on the actual system, and everything is closely followed by ConocoPhillips engineers in the operation support room in Aberdeen and online by the DTU Electrical Engineering and Eldor Technology team of researchers and developers,” states Erik Bek-Pedersen, DHRTC.

The first test performed well.

“We have succeeded in creating a continuous flow of data from the platform system to the AlarmTracker, and when an alarm goes on the platform, the AlarmTracker comes up with a root cause and the possible consequences if no action is taken,” says Erik Bek-Pedersen.

“In 2018, the development of the AlarmTracker advanced significantly,” says Programme Manager Erik Bek-Pedersen, DHRTC.

The focus was on the software, the user interface, and the central Multilevel Flow Modeling; the latter is the core research theme in the project - an advanced modelling technique, compatible with the operator’s decision-making based on artificial intelligence and data analytics.

In early 2019, the AlarmTracker performed its first real environment test at the ConocoPhillips’ Judy Platform in the North Sea.

The AlarmTracker team

The AlarmTracker is a result of a university-industry collaboration team of three companies and 24 scientists and engineers doing research and development into the monitoring, control and supervisory control of oil and gas production. The research and development are carried out with funding from the Norwegian Research Council under the Demo2000 program, Eldor Technology, Total (former Maersk Oil), ConocoPhillips UK and DHRTC. At DTU Electrical Engineering the research is performed by a team of four PhD students, two postdoctoral students, and two members of the scientific staff.

For more information on the academic work and the project: www.mfm.elektro.dtu.dk
Radial Jet Drilling (RJD) technology has the potential to increase oil and gas production from most of the existing wellbores in the Danish North Sea, where up to 70 percent of the oil in the underground are 'locked' or bypassed in the very tight chalk. This is the main conclusion of a DHRTC research project assessing the impact on production, and analyzing the stability of jetted radials in the Danish North Sea fields.

DHRTC is developing a prototype for designing and optimizing the placement of jetted radials. This work will be completed in early 2020, at which point the prototype will formally pass technology readiness level 3. “At that stage, we have documented the concept and value potential of the technology for the Danish North Sea fields. Still, in order to reach a level where it becomes feasible to apply the technology by jetting radials in the complex wells in the Danish North Sea fields, further development and testing are required. It will take further engineering efforts from Total and suppliers from the industry to make the technology ready for offshore use,” says Programme Manager Anders Bak-Jensen, DHRTC.

“The ultimate goal is to use the radial jetting technology without rig support at all, because that is the only way it makes economic sense for us offshore. The main areas requiring further development are downhole manipulation of the tool and deployment of the equipment while maintaining pressure control,” explains Michael Pitts, Lead Production Technologist, Total.

“We have had very good collaboration with Total and other partners from industry and research in working with this technology and bringing it towards the prototype level. It is now time for us to hand this prototype over to Total to consider the value in bringing the technology offshore,” ends Anders Bak-Jensen.
Innovative researchers have no expiry date

Although Jørgen Gross-Petersen has retired three times, he still has his mind full of innovative ideas for the oil and gas industry.

Lately Jørgen Gross-Petersen has focussed on applying modern polymer techniques to developing a pipeline that reduces scaling and lowers costs.

BY RIE JERICHOW

When Jørgen Gross-Petersen encounters a problem, he is inspired to develop a solution. By nature, he reacts like this, ever since he defended his PhD thesis 40 years ago and began a career with Maersk – at the beginning building ships, later working as an oil and gas facilities engineer.

After a long career as Chief Engineer he has retired three times. The first time was when he turned 65 in 2008. However, he continued with Maersk Oil and Gas until he took retirement a second time in 2016 - then only to continue as an advisor to the Danish Hydrocarbon Research and Technology Centre. In December 2018, he retired for the third time, when he formally stopped at the centre. But this was not the end of his innovative ideas.

Most recently, he and colleagues from Aarhus University completed the development of a new type of polymer pipeline to replace traditional welded carbon steel pipelines.

But what are the problems with carbon steel pipelines?

“Well, carbon steel pipelines have advantages, but there are certainly challenges as well. Especially, the risks of corrosion and scale entail costly repairs for the oil industry,” says Jørgen Gross-Petersen.

Corrosion resistant pipelines

For conventional carbon steel pipelines, a higher percentage of failures and incidents reported are related to corrosion.

Jørgen Gross-Petersen explains: “Obviously, this is a big problem. Therefore, corrosion resistant pipelines less prone to scaling would be a significant advantage for the offshore oil and gas industry. Polymer pipelines have a smooth surface, increasing the flow in the pipelines, and due to the flexibility of the polymer material, only a low pipeline tension is required during laying, and smaller and lighter laying gear is feasible.”

Since the polymer material is lighter than steel, its buoyancy presents a challenge, but this can be solved by adding a weight coat to the polymer pipeline. This will also prevent damage to the oil pipeline from fishing trawlers.

“We have now completed the project and are considering submitting a patent application,” he says.

The aim of DHRTC is to identify, develop and consolidate technologies that make it possible to increase the recovery of oil and gas.

“I have always liked the idea of bringing different research areas together – even short projects can turn out to be quite successful,” Jørgen Gross-Petersen says.

Even though the experienced specialist has formally retired, he will probably still be a regular visitor to the centre.

“I am still getting ideas. For instance, I am currently working on a new way to connect satellite platforms merely used to receive oil or gas from production wells to existing platforms – cheaper and faster,” he says with a smile.
Work in progress

Here you get an introduction to some of the projects that DHRTC is currently working on and the knowledge produced is expected to be ready during 2019.

What is to come

Liquid-repelling surfaces (LRS) have tremendous potential to increase the flow through the wells. It can reduce the energy cost for pumping as well as prolong maintenance intervals for removing scales and biofilms which can severely decrease operational costs. The beauty of the LRS coating is that it can be deposited in a simple solution with the already oxidized metal from the existing corrosion on current wells. In the labs at DHRTC the LRS is tested with state-of-the-art microscopy and spectroscopy techniques, ultimately tuning the chemistry for maximum protection of the oil wells. The ultimate goal is to bring the new LRS well coating toward testing under realistic conditions.

Well pipe samples used in the project. The well surface chemistry is analysed with ultrafast laser spectroscopy to optimise the coating technology.
The objective of this project is to identify the main controls on the deposition and distribution of clay in the Lower Cretaceous in the Danish Central Graben. This is done by constructing a stratigraphic model called DionisosFlow™ honoring observations and accounts for geological processes in the Valdemar area. This 4D model will improve the 3D static modelling by predicting facies distribution on the field scale and assessing the uncertainty associated with the geological model. 4D multi-lithology modelling is performed by incorporating the following parameters at each time step:

- Accommodation (subsidence + eustasy)
- Clastic sediment influx
- In situ sediment production (carbonates)
- Sediment transport (through diffusion)

Figure showing DionisosFlow™ stratigraphic model simulation results of the Tuxen formation deposition in the Danish Central Graben (a) showing the 3D facies distribution in the Valdemar and Adda areas at the end of deposition, and the location of sediment input used in this scenario. (b) Cross section through key wells used for model calibration showing the difference in facies development between the Valdemar and the Adda areas. (c) A wheeler diagram of the cross section in (b) showing the facies development with time together with the used eustatic sea level curve.
Hydrocarbon reservoirs as a major part of the deep subsurface biosphere host indigenous microorganisms that live under harsh pressure and temperature conditions. After thousands of decades, these diffusion-driven environments have been isolated and stabilized. However, this stability can be altered during petroleum exploitation. This may result in reservoir souring, a phenomenon through which H₂S gas is formed. Toxic and corrosive features of H₂S have made reservoir souring a dangerous and costly process. This is why, DHRTC has constructed a new model that helps to prevent or minimize reservoir souring outcomes and thereby enable optimization of inhibitor dosage. This model relies on considering different physiques such as multiphase flow, mass transfer and microbial metabolism, each one characterizing an aspect of the reservoir souring process. The aim is to develop the model further for commercial use.

The use of injecting seawater (water flooding) as a means of enhancing oil recovery significantly increases the possibility of corrosion failure of the tubulars as it increases the risk of water wetting the steel surface. Additionally, the chemical composition of the water fraction will change with time, and the overall temperature of the produced fluid will be lowered. All these changes needs to be evaluated with respect to material degradation and selection. Recreating these variations is challenging in a laboratory, but in this project the aim is to overcome the obstacles. Rigorous procedures and experimental set-ups are developed, opening up for understanding and determining the most important issues that needs to be continuously controlled and monitored. In 2019, DHRTC expects to introduce new techniques to monitor corrosion and scale formation. Those techniques will provide a greater understanding of the processes and the ways to mitigate it.
Google Earth of the subsurface

By loading existing seismic datasets into state-of-the-art seismic interpretation software and adding geological knowledge and interpretation, PhD Florian Smit has succeeded in exposing the buried sea floor of the hydrocarbon-bearing Chalk Group in the North Sea, like ‘Google Earth of the subsurface’. The aim is to enhance the prediction of reservoir quality.

BY RIE JERICHOW

Google Earth is a fascinating program. You can zoom in and out and see details that you never noticed before - or you can get a much greater understanding of the structure of the landscape. Now industry and academia working with recovery of oil and gas from the North Sea have a similar tool, making it possible to peel apart the hydrocarbon-bearing layers of the Chalk Group as a stack of buried Late Cretaceous sea floors.

3-D seismic images of sub-seafloor strata below the North Sea are not new. In the last 30
PhDs expected to finalise in 2019

- Maiya Medetbekova, Radial Jet Drilling, DHRTC
- Søren Dollerup Nielsen, Self-healing Cement, Aarhus University
- Michael Vigsø, InDirect Estimation of Loads from Abnormal Waves, Aarhus University
- Arifian Agusta Irman, Risk-based inspection Planning and Value of Information, DTU Civil Engineering
- Steen Hørsholt, Production Optimization, DTU Department of Applied Mathematics and Computer Science
- Jesper Dramsch, Deep Learning, DHRTC
- Leonardo Meireles, Rock mechanics and Fluid saturation study, DTU Civil Engineering
- Mattia Tagliavento, Sedimentology and reservoir geology, Copenhagen University
- Janina Kammann, Offshore P- and S-wave seismic surveys on Chalk Group, Copenhagen University
- Iris Fernandes, Geostatistical models based on deviated wells, Copenhagen University
- Kasper Blinkenberg, The role of Silica, Copenhagen University

18 years, the area has been thoroughly mapped seismically with the acquisition of individual 3-D seismic datasets which have recently been stitched together to allow a regional perspective.

The computational power to visualize these giant datasets has among other things led to an updated seismic chalk paradigm that provides new geological models for seismic features. These features were previously labelled ‘Funny Looking Things’, but now they have got a geological explanation.

“Within the last 20 years, the rapid development of processors and graphics cards have made desktop computers incredibly powerful, enabling them to perform comprehensive calculations of seismic attributes that we add as extra data to the buried sea floors. This allows us to extract more information from the seismic data and visualize it in a geologically intuitive manner,” Florian Smit says.

Geomorphological elements are revealed

In September 2018, Florian Smit defended his PhD thesis “Integrated seismic geomorphological analysis of syn- and post-deposition fluid migration features in the Chalk Group in the Danish North Sea” at Danish Hydrocarbon Research and Technology Centre.

In his study, he used algorithms from new software packages on these very big data sets in order to reveal geomorphological elements that made up the chalk sea floor, just as you would classify rivers and forests with satellite imagery of a landscape. By integrating well data into those elements, the added data provide clues to their geological origin.

Florian Smit explains: “Exposing these buried sea floors with advanced visualization techniques helps to generate initial ideas about what you are looking at. Adding petrophysical and geochemical data gives further information to what happened to the rock after it was buried, possibly affecting the reservoir quality.”

He stepped back a little and observed the different types of reflectors, asking himself what they could indicate in terms of geology; i.e. does a certain reflector indicate, that it once outlined a channel, a fluid expulsion event or an area of localized diagenesis - that is the chemical and physical change of sediments during burial.

“All of this might end up in seismic data as certain reflectors, depending on the velocity and density of the rock,” Florian Smit explains.

Useful findings

“When you understand what you see in the buried seafloors and understand their impact on reservoir quality, you can extrapolate the data from these findings to provide input for future well planning. Let me give a few examples. If we for instance see fluid expulsion features (e.g. craters) in a gas field, and we see the same fluid expulsion features in an area where we did not drill yet, it might indicate that it could be interesting to drill there as well. On the other hand, wells through these craters show highly variable reservoir quality, which lead to poor sweeping efficiencies as seen on time-lapse seismic data that
why one area is producing well and another area only poorly.

“Everybody is doing a different part of the project – integrating geology, geophysics, and geochemistry from seismic to nanoscale. I enjoy this way of working because we can progress much further when we work together. We have the same goal, but we are attacking it from different angles and at different scales”, says Florian Smit.

Florian Smit is now working on a new project, including all partners in the DHRTC. Here the researchers look at the Lower Cretaceous chalks from the same perspective to enhance the prediction of reservoir quality. In short, the project sheds light on where to drill and what areas to avoid, and it seeks possible answers to

An example of seismic geomorphological visualization of a buried chalk seafloor in the Halfdan gas field, where fluid expulsion craters can be observed. Logs are derived from the horizontal producing well, showing higher clay content within the craters than outside, likely leading to higher water saturations and poor producing trajectories. Modified from PhD dissertation.

On Monday 25 June, researcher Frank Niessen defended his PhD project ‘Phase transformations in supermartensitic stainless steels’, making him the first DHRTC PhD student to finish his studies. The project examines the major phase transformations in supermartensitic stainless steels which have the prospect of partly replacing Duplex-steels in offshore pipeline applications. The project generates a deeper understanding of the phase transformations and their impact on the mechanical properties. Frank’s project was a part of the CTR 2 work programme at DHRTC.

Let’s meet and share knowledge

Knowledge sharing

Upcoming knowledge sharing events in 2019

Young Researcher’s Day
24 May

Summer School 2019
12 to 17 August

DHRTC Technology Conference
5 to 6 November 2019

Keep an eye on www.oilgas.dtu.dk for more events.

BY ANETTE RIIS AND MARIA ENGKEBØLLE

The DHRTC partnership works to create innovative solutions that can be applied in the North Sea. That is not something that can be done by a small uniform group of people. It requires broad interdisciplinary collaboration and the right match between academic competencies and the technical challenges at hand. This is why DHRTC views knowledge sharing as a very important activity, says Lars Simonsen, R&D Director in DHRTC.

“We spend much energy connecting researchers with different competencies to solve the challenges of the Danish North Sea. In 2018, we hosted more than 40 seminars and workshops which makes the entire partnership more visible and works to inspire others to take our knowledge even further,” he says.

The purpose of the knowledge sharing initiatives is to provide meeting opportunities for researchers from different professional backgrounds.

“We offer attractive opportunities to bring people from across the country and many research areas together to develop ideas, solve challenges and write publications whether or not they are familiar with the oil industry,” Lars Simonsen says.

The centre also plays the role of broker between the industry and the academic environments at the partner institutions; Aalborg University, Aarhus University, Copenhagen University, Geological Survey of Denmark and Greenland (GEUS) and the Technical University of Denmark.
Work programme workshops

All the research programmes host application workshops several times a year with the purpose of sharing knowledge, networking, and presenting ongoing projects. The picture is from the Enhanced Well Chemistry and Integrity (CTR 2) workshop in December 2018. From left: Kashif Ali, PhD Fellow at Aalborg University, Hans Røy, Associate Professor at Aarhus University, Akinyemi Akinsanya, PhD Fellow at Aalborg University, Yue Guan, PhD Fellow at Aalborg University and Michael Faber, Professor at Aalborg University. Photo: Anette Riis

Young Researcher’s Day 2018

On 8 June, Young Researcher’s Day took place at DHRTC. More than 80 researchers from across the partnership participated in a day filled with knowledge sharing and networking. 45 posters were showcased at Young Researcher’s Day, where each participant had three minutes to present their poster. In the end, three posters jointly won the competition for Best Poster. Photo: DHRTC

Summer School 2018

The first DHRTC Summer School took place during two weeks in August 2018. The overall topic was Mature Oil Fields. As part of the programme in week one, the participants went on a field trip to the scenic Stevns Klint to get hands-on experience with the geology field.

The second week of the Summer School took place at Aalborg University Esbjerg, where the participants explored the port of Esbjerg as well as visited the offshore supplier SemcoMaritime and Total Engineering.

When DHRTC hosts events and workshops, the purpose is to connect the right academic competencies to the right technical challenges.

Welcoming secondary school students

Geoscience students from Danish upper secondary schools visited the laboratories at Aalborg University Esbjerg while other students simultaneously visited the laboratories at DHRTC in Lyngby. The day also included visits to industry, in order to introduce the students to possible career paths in the oil and gas research and industry.

Technology Conference 2018

The key word for the Technology Conference 2018 was interaction. More than 270 participants engaged in inspiring debates and discussions on several different topics related to the oil and gas industry. More than a hundred posters participated in the running for Best Poster. Every participant at the conference had a vote, which resulted in six winning posters. From left: Senior Reservoir Engineer at Total, Jose Maria Martinez-Val Piera, Research Assistant from Aalborg University Ying Qu, Associate Professor from Aalborg University Zhenyu Yang, and Research Assistant from Aalborg University Rolan Ossi. Photo: Joachim Rode
In your view, what are the most important DHRTC results?

DHRTC has been facilitating good collaboration and strengthened the network amongst the partner institutions. For example, the consortium project LOCRETA - Consortium for Lower Cretaceous reservoir analysis - has been absolutely fantastic so far. The local organization is central to this achievement.

What impact has DHRTC so far had on your university/institution?

DHRTC has helped our researchers gain more interest in and knowledge about the oil and gas industry. Consequently, AU has shown an engagement in DHRTC projects beyond expectations.

Future perspective: What is your view on future cooperation with DHRTC?

We hope that more DHRTC projects will prove applicable to the larger scale, and that therefore DHRTC will succeed in demonstrating the great potential within the national network of universities. We will achieve the ultimate success if this network continues to create excellent results with similar funding possibilities after 2024.

The Centre has also implicitly facilitated inter-departmental collaboration within AU.
In your view, what are the most important DHRTC results?

DHRTC has created a new focus on research related to oil and gas in Denmark. Moreover, an extensive database about Danish reservoirs and an excellent petroleum laboratory have been established. We see significant advances in studies of the recovery mechanisms, especially smart waterflooding. Equally important is the establishment and coordination of collaboration with experienced partners who have a track record, laboratories and the knowhow to drive the process of improving oil recovery from the Danish sector.

What impact has DHRTC so far had on your university/institution?

To be highlighted are the significant funding and the large amount of joint and cross-departmental projects in a wide range of fields (corrosion and scaling, gas injection, geology, etc). Overall, a very positive impact which has enabled research and researcher education to the mutual benefit of both our institution, DHRTC and the operating companies.

Future perspective: What is your view on future cooperation in DHRTC?

We certainly see the close collaboration being continued, maybe more focused on larger projects. We hope to see more initiatives regarding petroleum education as well and maybe more focus on basic research which can have a significant impact in the future.

In your view, what are the most important DHRTC results?

At the University of Copenhagen, DHRTC has stimulated interdisciplinary research between widely diverse specialties, including mathematical-numerical theory, chemistry and geology. Furthermore, theoretical approaches have been combined with geological field work.

What impact has DHRTC so far had on your university/institution?

The research has strengthened collaboration not only between internal departments but also with outside hydrocarbon-related research, thereby paving the way for future alliances.

Furthermore, the DHRTC collaboration has inspired us to connect basic research to technological applications in a novel context.

Future perspective: What is your view on future cooperation with DHRTC?

We see DHRTC as the engine driving future university-company partnerships, not only to improve hydrocarbon production in the Danish North Sea area, but also to ensure optimal energy transition in the years to come.

The wave measurements and wave simulations west of Anholt are highly interesting for geoscientists from The University of Copenhagen, and we will try to establish a close cooperation in the near future. In this respect the data transfer process is also a huge challenge and researchers from computer science wish to participate in this difficult and challenging task.
In your view, what are the most important DHRTC results?

I find that the single most important result of the DHRTC efforts is that it has sparked, and continues to facilitate, direct collaboration between many more scientists across the participating institutions. It has facilitated new contacts which I hope will exist way beyond the first decade of DHRTC.

What impact has DHRTC so far had on your university/institution?

DHRTC funding has helped keep important knowledge and experience within our organization through a period when slimming of the oil industry based on low oil prices otherwise could have made it difficult.

Future perspective: What is your view on future cooperation with DHRTC?

It was with great enthusiasm that we recently had the opportunity to discuss project results directly with the end user, the people in Total, who have the day-to-day experience with producing the fields. This direct new contact is very constructive and could lead to enhanced usefulness of both ongoing and future projects.
To do research and development, you need to have the right people. They need to know what to do, how to do it - and finally they must work together. This is not an easy task. Every second year, The Danish Hydrocarbon Research and Technology Centre is contractually obliged to provide an evaluation of these processes. The centre has good reason to be pleased with the 2016-2018 ‘grades’.

DHRTC is an infusion of young blood

BY RIE JERICHO

‘Keep up the good work’. It could very well be the words of a demanding but also satisfied parent seeing a child’s grades as successful as DHRTC’s biennial evaluation. The ‘grading’ of the last two years of work was carried out by OTM Consulting, which not only provides the analysis but also comes up with recommendations to support the strategic R&D investment decisions. The latest evaluation shows significant progress.

Shreekant Mehta, Director at OTM Consulting explains: “From 2016 to 2018 DHRTC has made a significant jump in all the areas evaluated and, in a short lifetime, DHRTC has become strong in the majority of them. It is quite an unusual situation.”

DHRTC plays with the big boys

In the evaluation, DHRTC is compared to a handful of similar organisations like Imperial College, Texas A&M and Schlumberger.

“These organisations have been working for many, many years to achieve their leadership positions. To be able to say that you are close on the heels of these organisations is quite something. DHRTC started in 2014 with an empty shell of a building and now in 2018 to be
in such a position is extraordinary – it really is,” Shreekant Mehta says.

The research areas which DHRTC focuses on are not unusual.

He continues: “The themes themselves are replicated in many areas and not unique, but the way DHRTC is pulling together the resources in the 130 different projects and the way they are attacked is entirely innovative and diversified.”

According to Shreekant Mehta, the oil industry today, in general, has a great need for innovative researchers.

“We have seen a great loss of people. There just aren’t enough clever, innovative researchers in the industry right now. The multidisciplinary nature of the work that DHRTC is doing is in high demand. The oil companies want to accelerate their production safely, increase recovery and reduce the uncertainty of their exploration and development programmes. It will mean a lot to Total that DHRTC is working on all three of these with a unique mix of scientific people and applications people. This is one of the really unique things that DHRTC has,” Shreekant Mehta explains.

On the other hand, DHRTC is also dependent on input from the oil industry.

“DHRTC needs focus and direction from the oil industry and the oil industry needs R&D capabilities from DHRTC. Young blood, so to say,” the OTM Director concludes.

OTM graphics

External evaluation: DHRTC is on the right track

DHRTC has made significant progress since the last evaluation. This is the overall conclusion of the OTM assessment from 2018.

The framework used in the evaluation of the DHRTC is divided into four themes, each with several sub-elements. Together they form an overall picture of the performance of the centre. The data in the evaluation is gathered from 14 interviews, 48 survey responses and supplementary sources. Here you will find the key conclusions of the evaluation:

Overall evaluation of ‘Quality of Objective settings’

Research focus is considered one of the centre’s strengths, yet the 100MMBOE objectives are beginning to look unrealistic as the centre moves closer to the 10 - year deadline

- Clear and good awareness of the overall (100MMBOE) and team objectives, but slight confusion about next steps following maturation of projects
- Research focus has expanded and become more defined, structured, and relevant to the objectives compared to 2016
Good progress from 2016 on creating an effective organisation structure, introducing collaboration and trust between the partners, yet industry communication and challenges related to the culture in academia still persist.

- The changes that have been made to the organisational structure in 2017 have been instrumental in enhancing the level of collaboration between the researchers.
- Internal communication has become more frequent and there is a clear strategy now for communicating with the community, and also in encouraging team communication on projects.
- A sense of community is growing between the local partners, and some progress on the international level.

Processes have grown from an embryonic and trial/error stage in 2016 to become well-structured and formalised. Effectiveness is yet to be established as some of the processes have just been launched.

- Good awareness and communication of strategy but some confusion exists about its effectiveness in enabling the centre to reach its objectives
- Strong financial planning, legal and compliance processes. Budgeting processes are enabling the centre to operate under a predicted capacity, but accuracy is challenged by cultural barriers.
- Informal processes for sharing knowledge still dominate, which is a good sign for creating a culture of knowledge sharing.
- Technology conference is one of the centre’s main achievements and has received positive feedback.
- Dedicated efforts to incorporate commercialisation in project plans, with some tangible results delivered in 2018

Talent acquisition to ensure progression of projects is still a persisting challenge from 2016, and upcoming headwinds through unclear industry-partners’ commitment are looming on the horizon

- Facilities are considered adequate for research purposes.
- The centre has grown in size since 2016, but talent acquisition is still a challenge that is affecting the progress of projects and expenditure.
Chalk has a very low permeability. Only in fractures, can oil flow more easily. But where are these fractures, how many are there, and what is their orientation? New fracture models that simulate the growth of the fracture network through geological time may give an answer. If successful, this technique could have significant commercial potential, not just in the Danish North Sea but worldwide.

BY MICHAEL WELCH AND MIKAEL LÜTHJE
Chalk is an important hydrocarbon reservoir rock in the Danish North Sea. It is made up of the skeletons of tiny plankton, crushed together very tightly. Because these grains are so small and so close together, chalk has a very low permeability, making it difficult for oil and gas to flow to through the rock to the wells.

However, chalk often contains cracks or fractures, formed when the rock has been subjected to stress over millions of years. The oil can flow much more easily through these fractures, so they play an important role when trying to control the movement of...
fluid through the rock. In order to plan how best to manage the chalk oilfields - where to drill wells, what pressures to maintain, etc - it is important to know where these fractures are, how many there are, and what is their orientation.

Unfortunately, you cannot see these fractures directly, except in a very few places where you have wells – and even then, you do not know how long they are or where they lead to. Standard industry practice is to build stochastic fracture models, where fractures are placed in random locations and given arbitrary sizes.

Existing models are poor at predicting fluid flow

These models are designed to be consistent with the fracture densities observed in the wells, and possibly with geophysical data or with fracture geometries in similar chalk exposed in onshore outcrops. However, there is still a huge amount of inaccuracy and uncertainty in these models, and they may not be geologically consistent. Therefore, they are poor at predicting fluid flow through the chalk.

The idea was to see if you could build much more realistic and accurate fracture models by simulating the growth of the fracture network through geological time, based on fundamental geomechanical principles. The hope is that this will give a fracture model which is consistent with the local and regional geology, and which can be built quickly and easily. This approach would also allow you to test the range of possible fracture geometries that would arise in different rocks under different geological histories, and therefore assess the amount of uncertainty in your predictions.

The model is built as a plug-in to existing software, used to create 3D models of the geology of oil and gas fields. This allows you to apply the model, not just to oil and gas fields, but also to fractured rock outcrops onshore, where you can check that the model predictions match the observed fracture patterns.

Good match between observed and predicted fractures

So far, the model has been tested on several onshore outcrops and in all cases, there is a good match between observed and predicted fracture geometry in all cases. Currently, the model is being tested on chalk fields in Denmark’s North Sea together with Total E&P Denmark.

If successful, this technique could have significant commercial potential, not just in the Danish North Sea but worldwide, including other industries such as geothermal energy and CO₂ storage. Patent protection for the technique has been submitted, while deciding on the best way to take this forward for commercial application.

Michael Welch and Mikael Lüthje are both Senior Researchers at DHRTC
Radical innovation Sprint

When you open a tap after the water supply has been disconnected, it often sputters and sprays completely uncontrollably due to air pockets in the water. Something similar takes place regularly in the separator, where production fluids are separated into oil, gas and water. A Radical Innovation Sprint project has developed an innovative solution on how to deal with this problem which is a challenge to production rate and process safety.

BY RIE JERICHOW

Slugs in the oil industry have nothing but shape in common with slugs in nature. A slug in the oil industry is an gas pocket leading to an unsteady multi-phase flow in pipelines. This is completely contrary to the desirable situation which is a steady flow allowing separation and production to continue unhindered. So not only are slugs troublesome to production, they can also pose a potential risk to pipelines and the environment. A Radical Innovation Sprint project has come up with a solution on how to deal with the elongated gas pockets.

“The processes that handle the separation of the production fluids are often not designed to deal with large fluctuations. They cannot keep up with the pace of such a burst. Therefore, severe slugs have negative effect on
Radical Innovation Sprint 2019

Radical Innovation Sprint invites people to explore the potential of the craziest, wildest ideas that has the potential to improve the production of oil and gas in the Danish North Sea. DHRTC offers funding to the ideas that might change the oil and gas industry, and over the past two years, about 25% of all submitted ideas were offered funding.

It does not matter whether the participants have a background in the oil and gas industry or not. The Radical Innovation Team will provide knowledge and help mature the ideas. During February and March, the team visits the partner institutions and host Ideation Workshops, where participants learn more about the Sprint and receive guidance from the DHRTC experts.

Deadline for application is 1 May. An external committee evaluates the submitted, anonymised ideas and decides which ones to fund. The research projects are to be completed during a three-month period, from 1 September to 30 November 2019.

A roadshow led to the idea of a project

Simon Pedersen is specializing in slugs. Three years ago, he completed his PhD thesis on the modeling and control of slugging flows. But he was curious to verify an idea of how to predict coming slugs.

When the Radical Innovation Team came to Esbjerg on their road show, Simon Pedersen heard about Radical Sprint and thought it was obvious to apply for funding here. Subsequently, he presented his idea to Martin Dalgaard Ulriksen who has a mechanical engineering background and a Ph.D. in structural dynamics. In this project, both their competencies would be necessary.

Simon Pedersen explains: “Today we have equipment to eliminate slugs more or less. One can, for example, open or close the valves or inject gas. However, the operator who makes these decisions does not have enough information to act at the optimal times. My idea was to capture vibrations from the slugs by installed accelerometers on the vertical part of the pipeline above sea level, so that the valves could adapt faster to the flow than today and thus optimize production.”

Although an accelerometer is a tiny measuring device, like the one Simon Pedersen is holding in his hand, the potential for exploiting the vibrations it captures is large. To the right is his research colleague Martin Dalgaard Ulriksen. Private photo.

Learn about Radical Innovation Sprint: www.oilgas.dtu.dk/english/Ideation/Radical-Innovation-Sprint
Slugs do not only create problems for production.

“They also create structural problems, because the vibrations from the slugs can cause fatigue in the pipeline. This affects the lifetime of the pipeline. So, if you can eliminate slugs, you can also extend the lifetime of the pipeline,” he says.

The idea is worth pursuing

A Radical Innovation Sprint project runs over just three months. Therefore, the two researchers very quickly made some simplifications to get an idea of whether their idea was worth working on.

“Within the time horizon, we managed to test our hypothesis. We now believe that by placing accelerometers on the vertical part of the pipe, it will be possible to distinguish vibrations from slugs inside the pipeline from vibrations originating from waves and wind. However, during a storm with high winds and large waves, it will be impossible to ascribe loads to the inner flow rates.” Simon Pedersen says.

The Sprint project has strengthened the scientists’ conviction that their idea is worth pursuing. They have now applied for funding for a major research project.

“We would like to improve our model to make it more accurate and more advanced. We will also investigate further where the accelerometer should be placed and whether two accelerometers placed offset will give us even more useful information. And finally, we will look into the valves to find out if - based on the measurements - they can be better at eliminating slugs,” Simon Pedersen says.
Four years ago, the DHRTC-administration began activities in an empty building with no comparable network-based research centre to emulate. Today, industry partners rate the financial planning as “impressive”. Four hundred contracts have been produced, and 50 financial controllers ensure that researchers can run their projects efficiently.

**How to operate with excellence**

BY MARIANNE BOM

The administrative staff in the DHRTC-network of research institutions does not have a slogan. If they had, it could be: “Probably the most efficient academic administration in Denmark”.

“Operational excellence is our main focus. We form the essential foundation in order to utilise the donation as effective as possible for the benefit of society, industry and academia,” says Elena Pachkova, Head of Administration and CFO at DHRTC. The administration is in charge of financial planning and controlling; the legal operations; the common data and
Profile of the CFO

Elena Pachkova has been Head of Administration and CFO at DHRTC since 2015. She has an international background, having been born in Russia, brought up in Germany, and studied in Denmark leading to a Master’s Degree in Mathematics and Economy (Cand. Scient. Oecon) and a PhD in productivity analysis from University of Copenhagen. Throughout her career, Elena has been fascinated by the financial and strategic perspectives of management and organization as well as improvements in internal processes. In her earlier career, she was Head of Business Support R&D at Carlsberg Breweries, Business Controller at the chemicals company Diversey A/S, and as CFO at the business planning provider WPA Mobile ApS, among other jobs.

IT security management; the construction and running of the laboratories at DHRTC; communication and daily administration.

These activities create the operational foundation of the centre. The scientists would not be able to do their jobs efficiently if the technical and administrative staff were slow, incompetent or unwilling to suggest innovative solutions in the complex context of five research institutions and several industrial partners.

Positive feedback in evaluation

“The 250 researchers in the DHRTC-network need a flexible and agile administrative system. They do not want to sit and wait a long time before we tell them whether they have the money to start an urgent project that is important for their mission. They also want contracts to be swiftly set up and signed,” says Elena Pachkova.

In 2018, an evaluation of DHRTC performed by OTM Consulting took place. It shows that Elena Pachkova and her 11 colleagues at DHRTC, in collaboration with a total of 100 controllers, technicians, lawyers, and other administrative personnel at the five partner research institutions do a remarkable job.

The administrative processes are rated “strong”, and the industry partners as well as DTU Management consider the financial planning and management process “impressive”, according to the evaluation.

“Four years ago we began activities in an empty building. We met five research institutions each with their different administrative management traditions that we needed to integrate, and we could find no comparable network-based research centre with a best-practice to copy,” says Elena Pachkova.

Sharing a passion for excellence

“It has not been an easy task. The institutions saw each other as competitors, and we asked them to change their attitude and become fellow players. At the same time nobody wants people from the outside to instruct them how to do their job. So for us it was not an option to go out and tell our colleagues in the network how to do their job,” says Elena Pachkova.

Instead, she and her colleagues entered into a dialogue with their partners to define the issues of common interest, and what the partners wanted to achieve together.

It turned out that once a personal relationship was established, Elena Pachkova and colleagues met a lot of highly competent people sharing a passion for operational excellence.

"In reality we asked them to worker harder, as we were laying out the rails while the train was running, and I want to express my gratitude to all who participated," says Elena Pachkova.
Achievements

Financial planning and management
More than 50 controllers have succeeded in establishing and running a process to budget and forecast expenditure, time, and human resources needs for projects. Every quarter the controllers produce 150-200 reports, providing a forecast deviation of five to six percent, which is excellent in an academic environment considering the complexity of the centre. This shows that the available resources are effectively spent in DHRTC. On top of that, it helps DHRTC to ensure that the donation is invested in the best possible way.

Legal operations
The DHRTC has set up legal compliance standards for confidentiality, publications, contracts, and 3rd party agreements. The network has delivered 400 contracts over the years. In average that is more than three contracts every five workdays.

Data management/IT
To share data openly while at the same time comply with confidentiality rules, DHRTC has established a common data storage, and is a frontrunner in secure data management, utilising two factor identification, encrypted hardware, and electronic lab notebooks. Additionally, all meeting rooms are equipped with video conferencing to facilitate collaboration within the DHRTC network.

Labs
DHRTC has established fully equipped state-of-the-art laboratories in Lyngby including reservoir fluid characterization, core flooding, CT scanning, and SEM equipment. A broad group of researchers and technicians are running more than 500 experiments on the site per year and the experimental activity is rising. Going forward, the plan is to open up the labs even more to the network.

Communication
A shared communication and branding platform has been developed for the entire partnership. Social media presence has been established with more than 500 followers of DHRTC on LinkedIn and almost 15,000 unique visitors on the website annually. Annual reports have been published in print and on the website every year to share results and knowledge. An important aim of the DHRTC communication is to help people network and share knowledge, information, good practices and to socialise. A major annual event is the DHRTC Technology Conference with more than 270 participants.

Operations
The administrative operational team is the backbone of the effective handling of various daily tasks from purchasing, planning and organizing events, payments and welcoming new colleagues to DHRTC.