The First

SPE Norway Magazine

To gather members
To share knowledge

SPE International

Norway Council

Volume 1, 2018 Norway

Norwegian Ilmenite Solves Drilling Challenges

Norway One Day Seminar

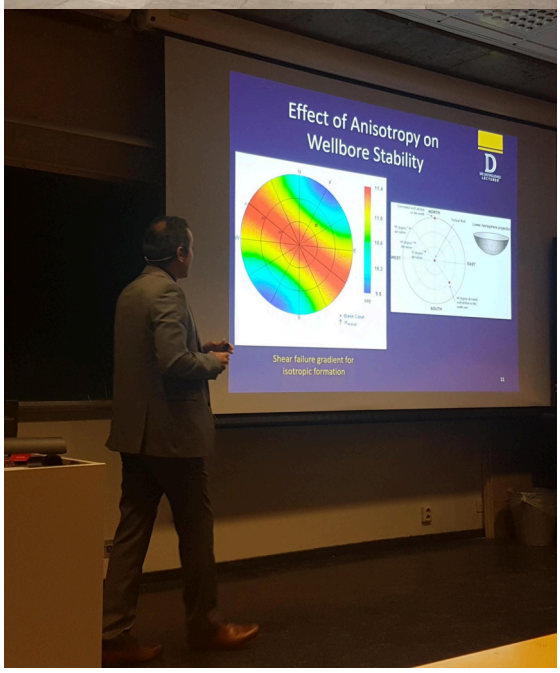
Hole Cleaning Performance

Big Data Solutions

SECTION NEWS

Picture by Tapio Oskari Järvinen (Palfinger Marine Norway)

Articles from the Industry



EDITORIAL CONTENT

INSIDE THE ISSUE

Dear SPE Norway members,

First of all, we would like to thank for all contributions from the sections and the industry we have received for the first issue of 2018! Your editorial contributions are what makes this magazine great, helps us to promote knowledge sharing across the sections and across the companies.

We would like to encourage you to be even more active this year and submit your articles to The First Magazine. Our readership is expanding and online publication helps with a rapid growth of readers. This publication is a brilliant opportunity for you to promote your research and technological advancements.

On behalf of the editorial team,
Giedre Malinauskaite (Marketing Manager, FourPhase, email: gma@fourphase.com)
Maria Djomina (Communications Manager, AGR, email: maria.djomina@agr.com)

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Igor Orlov
SPE Norway Council Chairman

Congratulations! We are back into the period of growth and increasing level of activity in the Norwegian and international markets. Oil price reached 70 USD per barrel and independent prognosis indicate 65 USD per barrel level in the forecast for the upcoming years.

Busy times always raise a question of volunteering value and need to participate in non-work related meetings (as well as using unpaid hours). Many consider that their companies provide enough development and networking to avoid being an active part of other professional communities.

I would like to share my view on this matter. Being working for one of the industry leaders, I can state that our working environment is excellent with high-quality network meetings and development program of a few courses per year. Meanwhile, I have been an active member of SPE for the past 10 years and always enjoy being part of the SPE community.

I feel that SPE along with other volunteering organisations give a person that extra 20% needed to be professionally and personally satisfied. It is like having family and friends, work for me is still family, but SPE is my close friends I need always and those two (family and friends) always go well and complement each other.

Below are a few reasons why I am a part of SPE:
• To meet and know professionals outside of my working environment. It's a way to hear new points of view;
• To participate in meetings outside of my core area and learn the methodology from different topics;
• To create a difference in the new area - SPE volunteering provides you an opportunity to try and make changes outside of your workplace and push outside of your comfort zone;
• To get energized and have fun.

At the end of this welcome page, I would like to invite you to the SPE Norway One Day Seminar which you previously knew as a Bergen One Day Seminar. The seminar is the best technical event in Norway with its old history and excellent technical and organisation crew. It will help you to be smarter, faster and more excited about upcoming years in the industry.

Respectfully,
Igor Orlov
SPE Norway Council Chairman
2016-2018

SPE for the Future

In my previous message in this magazine the oil price was around 55 USD and at the time of writing, the Brent oil price is now at 67 USD. However, between these two points in time, the price for oil has been as low as 44 USD and as high as 71. Many oil market analysts tell us that it will be like this going forward, volatile! Market expectations that US will become a net exporter of oil, the major lack of investments in conventional oil projects seen in the years after the oil price crash (the last one..) and the uncertainty of the growth in global oil demand; are all a big part of why the price is expected to be volatile. When I started my career in 2005, the oil price was climbing to record highs of 50 USD/bbl (and beyond) and now, 13 years later the one year oil price average is very close to that price in nominal terms, so putting things into perspective, the price for oil is cheap. This fits well with market predictions of this business' future, volatile and more competitive. Oil will come more in competition with other energy sources. For instance, today, oil basically has a monopoly on transportation, but as we see around us it is changing; especially in the light vehicles segment. The peak oil demand debate is a hot topic and very similar (and just as difficult) as the peak oil supply debate was, the outcome is in a way the same, new energy sources. However just the fact that oil supply now is so high with huge resources there to sustain it, that gives me the utmost belief in this industry and our products. Oil is a resource that the world needs and that has so many known areas of application. Technology and cost is what has driven renewables the last 10 years due to the very high oil price of over 100 USD/bbl. These areas will also drive the oil business going forward making it able to deliver on schedule and cost and being profitable. I am excited about the future of oil and I look forward to being surprised of new areas/applications where oil will emerge into.

As excited about the future of oil I am equally excited about the future of SPE! Our society lives with and by the oil industry serving our members who are employed there. Recently there have been some changes to the international board structure and geographical regions in SPE that I briefly would like to share with you. SPE International Board of Directors (SPE BOD) have in the recent years seen a need of a board that is more agile and efficient in its execution. At the March 2016 board meeting, a task force was established to evaluate the size and composition of the board to ensure it reflected emerging demographics from a regional and technical focus perspective. Other key drivers were ensuring that the board retains a strategic focus (smaller boards

Karl Ludvig Heskestad
Regional Director North Sea
Aker BP ASA

are more strategic) and cost containment. The task force recommendations were approved by the SPE BOD at our October meeting during the 2017 SPE Annual Technical Conference and Exhibition. In the revised board structure, board membership will be reduced from 27 to 19. Changes to the board structure will be phased in over the next 3 years as the terms of current board members end. Further details can be found in the JPT December 2017 edition which is available online at spe.or/jpt (or in your hard copy version that you receive every month as part of your SPE-membership). For our region the impact from this revision means that our North Sea region will be merged with South, Central and East Europe region (excluding Russia) in Q4 2019.

As our region grows in size and members National Councils like the SPE Norway Council will grow in importance and it is very comforting to see the impressive work the Council in Norway is doing. I am going to the SPE Norway One Day Seminar in Bergen in April to meet with the SPE Norway Council and to attend the conference and exhibition and I do hope to see many of this magazine's readers at the presentations and at the various booths!

Author:
Karl Ludvig Heskestad
Regional Director North Sea
Aker BP ASA

REGISTER NOW

Changing Industry Context – Challenges and Opportunities within Drilling, Reservoir Management and Production

SPE Norway One Day Seminar

18 April 2018 | Hotel Edvard Grieg | Bergen, Norway

Co-Chairs

Lill Harriet Brusdal **Statoil**

Petter Sørhaug **AkerBP**

The only dedicated event in Norway addressing well, drilling, completion and intervention issues.

Conference Highlights

- Two operator panel sessions
- Six technical sessions
- Exhibition
- Networking reception
- Young Professionals' reception and luncheon

Host Organisation

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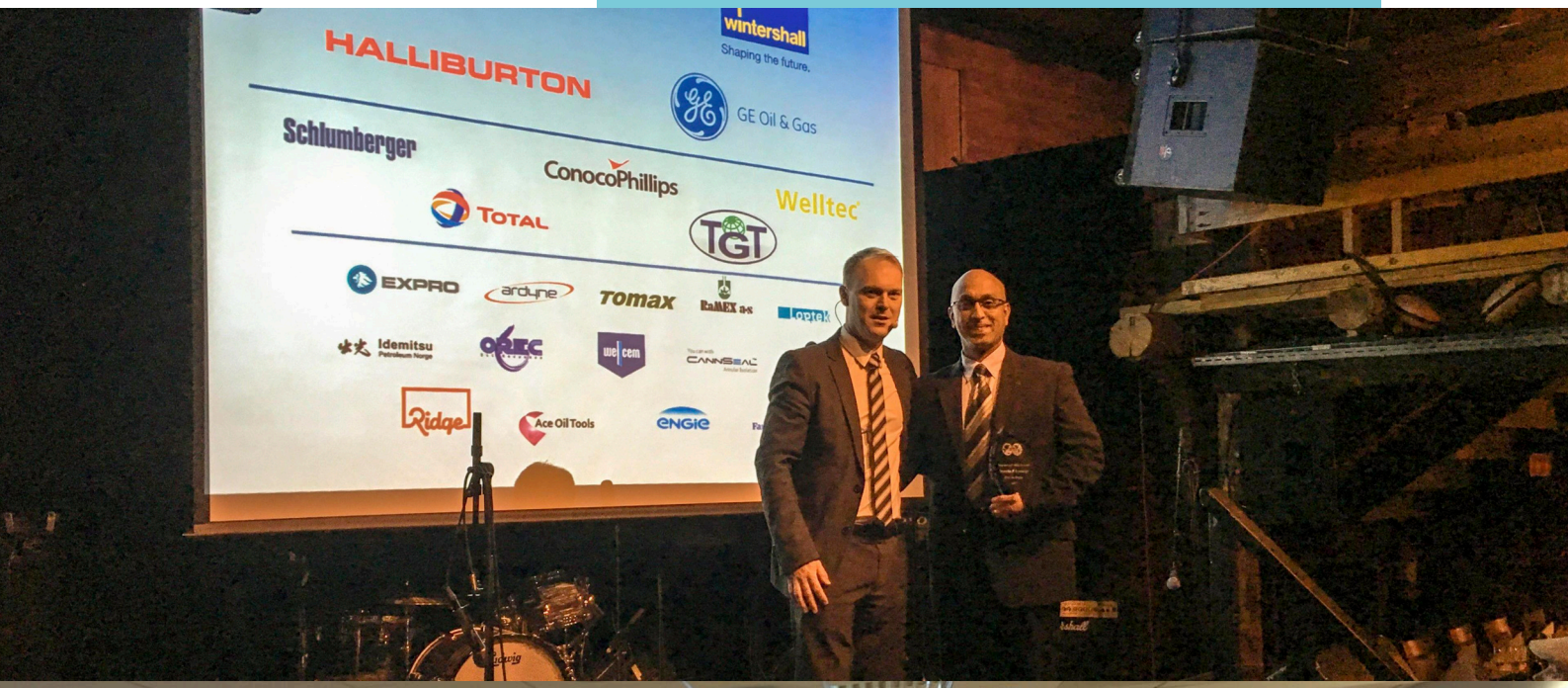


Pictures:

1. Prof. Jayantha P. Liyanage, PhD, was handed over the 2017 Management and Information Award

2. January's technical section

Dear SPE Members,

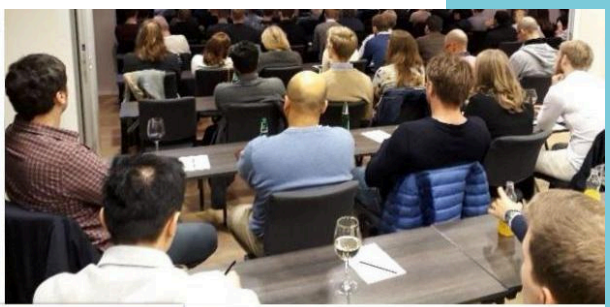
We have entered a new year that also looks to be the start of more activity in the oil and gas industry. In SPE we continue to support our sponsors and members by arranging the meeting arenas to connect people across businesses and to educate our members.

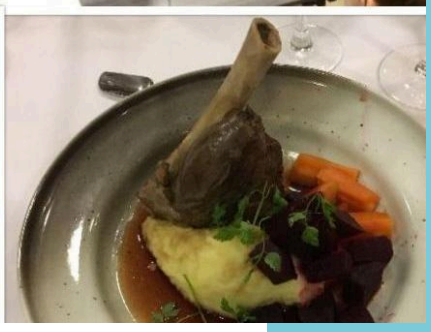
I was very pleased to see so many happy faces attending the SPE X-mas party in

“Stay connected with us on our website and social media, and do not forget to renew your membership! ”

Stavanger December 2017. In addition to meeting great people, eating good food and being entertained by magicians flown in from France, we also had the pleasure of handing out an award. **Prof. Jayantha P. Liyanage, PhD**, was handed over the 2017 Management and Information Award for his significant contribution to the industry through his academic position at the University of Stavanger and his initiative to establish the regions Cluster for Asset Management, which in the true spirit of SPE identifies challenges and brings academic resources together with the industry to better develop the future methods of bettering all aspects of industrial asset management. – Congratulations and well deserved!

In January we resumed the monthly technical lectures, and we are glad to see the lectures are popular and attracting many of our members and more. The February lecture event was dedicated to our **Young Professionals** that had pulled together a fantastic program for a **Researchers Night** using technical resources from the **University in Stavanger (UIS)** and the research environments and organizations in connection/vicinity of UIS. Again this was a well-attended event, not only for the lectures but also for the dinner after the lectures. A great thanks to the SPE Young Professionals Board for a well-accomplished event!



Author:

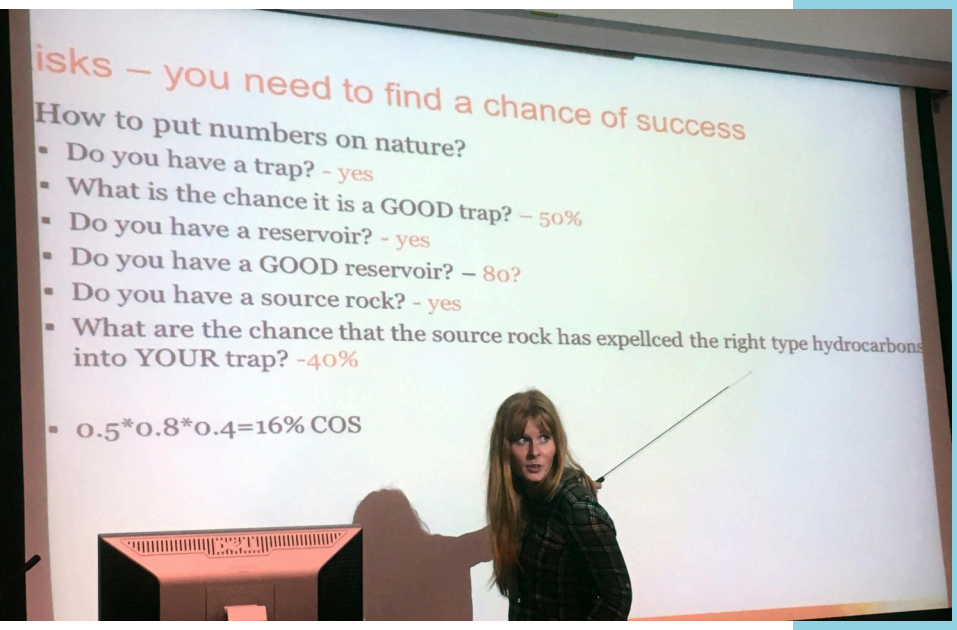
Vidar Strand
SPE Section Chair
Stavanger

Company Presentation by Lundin Norway

On the 26th of February, the Student Chapter had the pleasure of hosting a company presentation by Lundin Norway at UiO.

Petroleum System Analyst Jon Halvard Pedersen and Seismic Interpreter Sara Sandvik gave a wonderful presentation about the company and how its like to work as a geoscientist in Lundin. The attendees especially enjoyed the stepwise introduction to maturing a prospect. A lovely afternoon was ended with delicious pizza. In the picture, Sara is showing how a geologist contributes to calculating chance of success.

More companies are also showing interest for company presentations and the spring semester for the Oslo Student Chapter, therefore, looks bright. The semester quiz and the annual Spring Games is also currently being planned.



Author:

Ole Kristian Bergsland Hansen
MSc Candidate, Geology, UiO Chairman, SPE Oslo Student Chapter

Bahador Najafiazar
Chairman

Hassan Karimaie
Past Chair

Ashkan Jahanbani Ghahfarokhi
YP Chairperson

Cleide Vieira
Membership Chairperson

Igor Orlov
Treasurer

Kristine Owe
Student Chapter President

Pictures:

Current SPE Trondheim Section Officers

SPE Trondheim section's first board meeting of the year was held on January 31st, 2018, with its new board members.

The main objective of the meetings was to set the goals for 2018 and to distribute tasks among the officers, accordingly. The current board is composed of the following positions: Section Chair, Past Chair, Department Head, Treasurer, YP Chairperson, Membership Chairperson, and Student Chapter Liaison. However, it is lacking

“Next Young Professional event will be on Thursday, April 19”

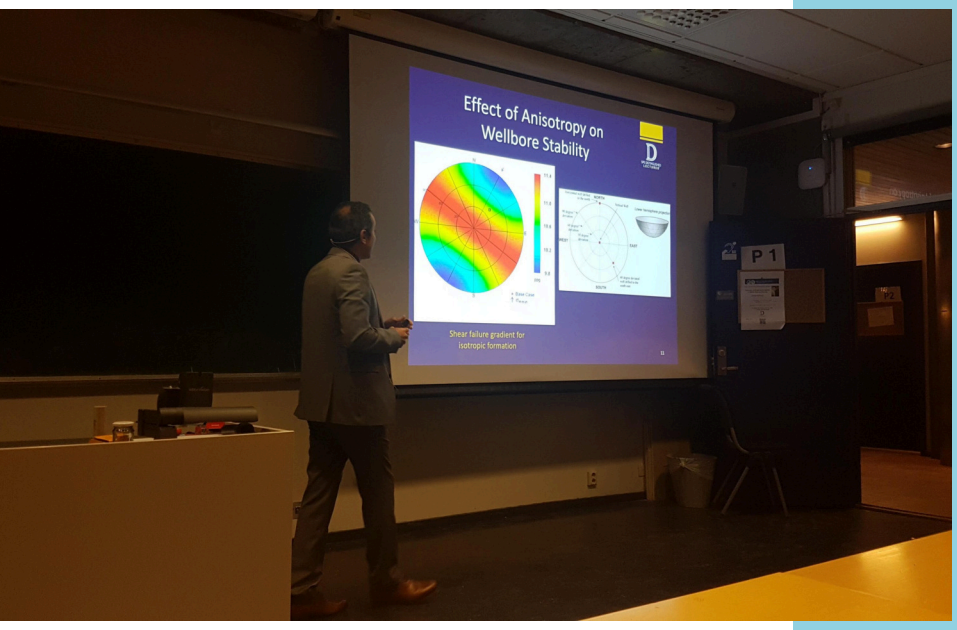
one of the main positions -Communications Chair. The tasks of this position have been distributed among other section officers as a tentative solution. In the meantime, we are looking for interested professionals to add to the board and fill the gaps.

Next Distinguished Lecturer Event

Our next distinguished lecturer event will be on Monday, March 19 starting 11:30 AM at the Department of Geoscience and Petroleum, NTNU. The Lecture will be given by Ann Valentine, and the topic will be “Integrated historical data workflow: maximizing the value of a mature asset".

Next Young Professional Event

Our next Young Professional event will be on Thursday, April 19 starting 05:00 PM at the Department of Geoscience and Petroleum, NTNU. Malin Torsæter, Espen B. Raknes, and Kjetil Lorentzen are among the speakers at the event.



Picture:

Last DL event, presentation by Hamed Soroush (Dong Energy) on "Isotropy: A Fatal Assumption in Shale Geomechanics"

Author:
Bahador Najafiazar
SPE Trondheim Board

Bridging the gap between students and the petroleum industry

The Student Chapter in Bergen works to connect students and the petroleum industry in the Bergen area closer together. Through social events such as company presentations and TechNights held by SPE Bergen, students are given a great opportunity to meet professionals and get to know the industry. This semester we have four different events planned including a semester kick-off and a company presentation by Lundin Norway.

On the 1st of March, the SPE student chapter will host a Semester kick-off where all the students at the natural science faculty are invited to attend. It is a social event where students can meet new people with common interests.

Our most popular events are the company presentations by different petroleum companies. This spring, on March the 20th, Lundin Norway is coming to the University of Bergen to talk about the company and to give students insight into how they approach challenges. After the presentation there will be served food for everyone attending.

Presentations such as this, is especially popular for the petroleum and geoscience students, but also amongst other majors.

Picture:

Last years PetroBowl team in Kraków, 2017. (taken by Njål Frafjord)

SPE Bergen Student Chapter

It is a great opportunity for students to get a better understanding of the industry and realize what the industry has to offer, especially now that activity on the Norwegian continental shelf is picking up again.

"We are always looking for new student-industry collaborations!"

We are also planning to send a team to the annual PetroBowl European regional qualifier in Kraków. It is an international competition where SPE student chapter teams from all over the world compete in a quick-fire quiz with petroleum-related questions. It has been a success in the past years, and the Bergen team hopes to qualify for the championship round, this year held in Dallas, Texas during the ACTE 2018.

We encourage everyone to follow our pages on Facebook and Instagram to get the latest updates on our events and how you can get involved with the section. **You can find us by searching for: spe_bergen_student**.

Also, if you have ideas about the companies you would like to see at our presentations or you are a company looking at ways of engaging students in Bergen - get in touch with us! We are always looking for new student-industry collaborations!

Author:

Amalie Rott Ellingsen
Student Chapter President
SPE Bergen

One Day Seminar in Bergen in new venue

The traditional petroleum engineering conference ODS runs in Bergen April the 18th. The famous composer Edvard Grieg is stilling following as a ghost in the walls. This year we do not meet in the Grieg Concert Hall in central town, but in the Quality Hotel Edvard Grieg at Sandsli. The venue site is in the neighborhood of Statoil. It is close to a dozen oil service and drilling companies, and 5 min drive from Bergen airport.

ODS is still the largest and most important petroleum engineering conference. The latest news in technical research and newly developed methodology are to be revealed in more than 40 exiting presentations.

The conference will be opened by the mayor of Bergen and followed by a panel discussion where managers from central companies are showing their visions for our industry.

As for the previous years, a larger number of companies will show and demonstrate their technology. And of course, we'll finalize the exciting day with an entertaining dinner and party.

All the speeches and digital posters will be published as SPE papers and provided to all conference delegates.

This is the best opportunity to upgrade your competency and maintain your professional network.

Picture:

SPE One Day Seminar is moving from it's previous location to a new conference center in Quality Hotel Edvard Grieg in order to be closer to the industry and to attract even more industry professionals.

Author:
Torbjørn Kaland,
SPE Bergen Board

DNV GL launches certification framework and recommended practice for Carbon Capture and Storage (CCS)

According to the IEA, building CO_2 transport and storage infrastructure is critical to unlocking large-scale CCS deployment. CCS is central to a 2°C pathway, as part of the least-cost portfolio for power and as an essential mitigation solution in the industry. Large-scale roll-out of carbon storage is vital to achieving the

"We now have further confirmation that we are technically ready to be able to use large-scale CCS"

climate goals under the Paris Agreement.

DNV GL has launched both a framework for certifying geological storage of carbon dioxide (CO_2) and an updated recommended practice for the design and operation of CO_2 pipelines. The certification framework serves to improve stakeholder dialogue and investor predictability, and the recommended practice provides a recipe for the safe transportation of CO_2.

The DNV GL certification framework enables verification of conformity with the new ISO standard, ISO 27914:2017 Carbon dioxide capture, transportation and geological storage – Geological storage. This standard represents an international consensus on the requirements for the safe and effective storage of CO_2 in geological formations.

The recommended practice DNVGL-RP-F104 Design and operation of carbon dioxide pipelines, provides guidance on safe and reliable design, construction and operation of pipelines intended for large-scale transportation of CO_2. The recommended practice enables compliance with the requirements in the new ISO standard, ISO 27913:2017 Carbon dioxide capture, transportation and geological storage — Pipeline transportation systems.

CEO of DNV GL - Oil & Gas, Liv Hovem states that "We now have further confirmation that we are technically ready to be able to use large-scale CCS for onshore and offshore emission sources. Our new certification framework plus our recommended practice represent an important step towards making the full CCS chain technically feasible, safe and ready for global scaling."

"ISO 27914 represents a key step towards creating trust in CCS and making it credible as a safe and effective technology for reducing CO_2 emissions"

CO2 emissions from large emission sources. It will serve as a key reference document for the execution and approval of projects aimed at the geological storage of CO2 worldwide."

The DNV GL certification framework provides additional clarity about the requirements an operator should meet – and offers a recipe for how to meet them – at different points in the lifecycle of a geological storage project. It thus improves investor predictability and decreases both capex and opex risks.

It has also been subject to a broad international consultation process and received significant support from potential users. One of the certification framework advocates, Luc Rock, a hydrogeologist - MMV Coordinator with Shell, says:" The certification framework makes ISO 27914 requirements and recommendations easier and more accessible by grouping them according to their relevance for decisions. Putting foundations like this in place are part of the industry's drive that will hopefully kick-start the growth of CCS as a cost-effective method to remove global fossil fuel emissions."

DNV·GL

Liv Hovem
CEO
DNV GL - Oil & Gas

Big Data Solutions For Mitigating Risk During Drilling & Workover Operations

I DATA AQUISITION

Enterprises have unique features and differ from each other in the services they provide, their corporate culture, their locations, policies and procedures, caring for the public and charity, or operating for shareholders and profit.

"Big Data analytics is used in real-time during Drilling and Workover operations to predict and prevent problems"

The one thing enterprises have in common is that they need to make decisions; the better the decisions, the more successful the venture. Decision makers who based their decisions after considering relevant facts, and accurate information gathered in a timely manner, will prosper.

The need for gaining competitive advantage, reducing costs, improving service, and streamlining operations has driven organizations to invest in efficient data acquisition systems. Over the last decade, these systems have provided enterprises with databases that contain a wealth of information, and recent improvements in sensor technology has given rise to real-time database proliferating the Internet of Things. However, simply gathering more data does not automatically lead to useful information or better decision making. IBM stated that "the percentage of data an enterprise can understand is on the decline. A further complication is that the data the enterprise is trying to understand is saturated with useful signals and lots of noise. [1]."

Data acquisition in enterprises usually stemmed from the application of technology to address a business need or meet mandatory regulatory compliance. Large volumes of data were collected and stored as a direct result, or by-product of systems. This data arrived in a variety of formats, and in the case of sensors at a very high velocity. This paper is based on real occurrences in the Oil and Gas industry. It describes the situation where the application of Big Data analytics is used in real-time to Drilling and Workover operations to predict and prevent problems. It concludes providing implementable techniques for applying Big Data solution towards similar problems.

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II. BIG DATA TECHNOLOGY AT DRILLING OPERATION

Oil & Gas industry today is looking to cut costs, run safer operations and extract value from technology. “The term Big Data refers to more than simply a large volume of different types of data, both structured and unstructured, with varying degrees of accuracy. It also includes a suite of applications providing solutions and analysis. The big data approach is said to be a data-¬centric method adept at uncovering otherwise invisible patterns and connections by linking disparate data types. [2]”

Drilling & Workover form a key part of Upstream business drilling and completing new wells, and performing workover activities on existing wells to meet target production. Drilling operations have been gathering and analyzing data for decades. Daily activities, and well completion data are meticulously recorded and reported as part of daily operations.

““The term Big Data refers to more than simply a large volume of different types of data”

With the advent of real-time drilling data for measurements while drilling (MWD) and logging while drilling (LWD), the traditional data stores are now complemented with real-time streaming data arriving from drilling rigs around the clock. This presented an opportunity to use Big Data technology to further optimize drilling operations.

III. DRILLING TROUBLES

In an Oil & Gas enterprise, Drilling & Workover operations perform a key business function of bringing the asset to the surface. This requires performing operations which drill holes at depths of over 20,000 feet, establishing contact with the target reservoir, and stabilizing the hole by running casing and production tubing to safely produce oil and gas without potential leakage and harm to the environment.

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non-productive time during drilling operations, resulting in safer operations and cost savings.

IV. APPLYING BIG DATA TO DRILLING TROUBLES

Big Data can play a part in performing advanced analytics on various data sets collected during Drilling & Workover operations to reduce drilling troubles. Data sits in traditional database, in the form of morning reports which are entered by rig foremen on a daily basis recording the type and duration of operations, the comments entered for tasks carried out during the operations, the real-time MWD and LWD readings taken during drilling operations, and data gathered from offset wells. Combining all of these in real-time can lead to insights and breakthroughs not seen before.

Big Data analysis helps synthesize the information and creating a drilling profile for a well. This profile is used as a baseline to identify abnormalities

"Big Data can play a part in performing advanced analytics on various data sets"

Drilling technology has seen many innovations over the years and is now able to target pockets of oil in tight zones at increasing depths and hard to reach angles. While this allows companies to recover more hydrocarbons than before, it is not free of problems.

Drilling troubles include borehole instability, high or low drag on a drill bit, stuck pipe problems, and low rates of penetration etc. Minimizing outages due to these problems can decrease the or variances while conducting drilling operations.

Analysis is performed in real-time to correlate drilling parameters, and cross-check them for patterns of behavior, and find leading indicators for ensuring safe operations. Some examples of how this was successfully applied is shown in the following sections.

A. Stand Pipe Pressure Analysis

Big Data techniques were applied successfully to analyze Stand Pipe Pressure (SPP). The data below shows the parameters which were correlated and analyzed including Stand Pipe Pressure (SPP) and Drilling Fluid which helped predict early signs of Bit problems, Bottom-Hole Assembly BHA / String trouble, and hole cleaning conditions.

Figure-1 plots the Flow-in, the Stand-Pipe-Pressure (SPP), and the Calculated Stand-Pipe-Pressure (Calc_SPP) curves. The relationship between these is used to highlight drilling pattern.

The Flow-in in Figure-1 is almost constant from point A to point C. from point A to point B the SPP curve and Calc_SPP curve are mostly aligned, which indicates normal operations within an acceptable range. Note that at point B, the Flow-in curve has not changed. However, SPP trend is beginning to decline, and SPP and Calc_SPP are starting to drift apart which indicates that the SPP is showing the beginning of abnormal well behavior. SPP continues to decrease until it sharply decreases at point C, where the operation was stopped.

Big Data techniques were essential in identifying Calc_SPP which was able to identify abnormality in the drilling operation and predict the risk at an early stage before it matured to a major drilling trouble. It is worth mentioning that using Calc_SPP provided the operational crew with a bigger window of +1 hours to identify the abnormality in the SPP values, comparing to traditional monitoring process.

“ Big Data techniques were essential in identifying Calc_SPP which was able to identify abnormality in the drilling operation ”

The Flow-in, measures the flow of the drilling fluid in gallons-per-minute. The Stand-Pipe-Pressure (SPP) measures the drilling fluid pressure within the drilling string up to the surface through the annulus. The Calculated Stand-Pipe-Pressure (Calc_SPP), is a calculated curve for the well behavior model developed on analyzing and correlating the Flow-in with the Stand-Pipe-Pressure. Calc_SPP represents the normal SPP values associated with the Flow-in behavior. As a result, when the SPP and Calc_SPP curves are aligned, the operation is considered normal (from an SPP point-of-view). As the values deviate, alerts needs to be raised.

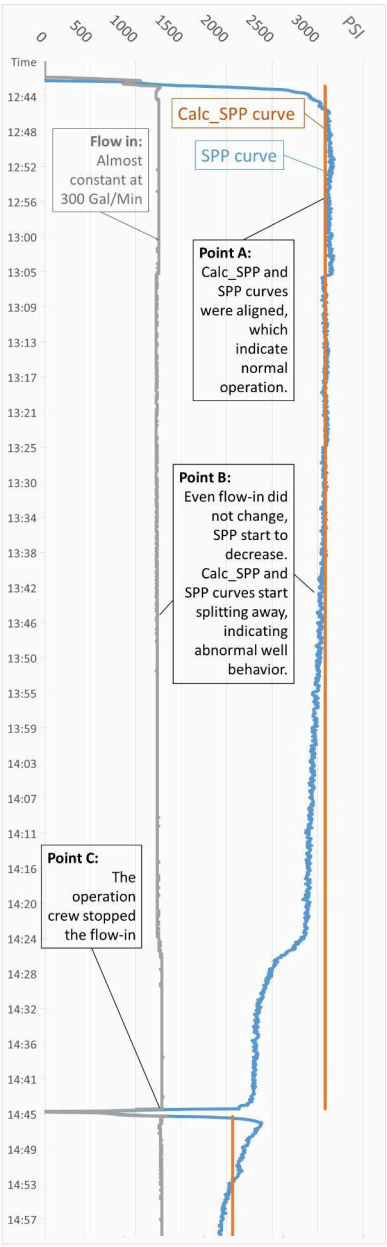

Figure 1 - Stand Pipe Pressure to Predict BHA Problems

B. Hook Load Analysis

Hook load plays a critical role when making footage while conducting Drilling operations. Finding the right correlation between the hook load, depth and trajectory can be of benefit during drilling as the analysis can guide drillers through tight zones more effectively. Furthermore, examining the impact of hook load can provide early detection of stuck pipe and prevent mechanical stuck pipe problems.

Figure-2 plots the Hook-load curve, and the Calculated Hook-load curve (Calc_HK). The Hook-load curve presents the total forces needed to pull a drilling string from the well hole. The Calculated Hook-load curve (Calc_HK) is a calculated curve developed by analyzing and correlating the Hook-load behavior with the well's trajectory. The Calc_HK values present the expected normal Hook-load for each trajectory point. If the Hook-load and Calc_HK curves are aligned, then the operation is considered smooth from a Hook-load point-of-view. Otherwise, the deviating curves indicate an overpull condition!

In Figure-2 the Hook-load is higher than Calc_HK at point A which indicates an overpull situation. During a pull out operation, the Calc_HK is showing lower Hook-load values, in contrast with the actual Hook-load curve which shows increasing values. This indicates an increase in overpull, which is highlighted at points B and can be interpreted as an early symptom of stuck-pipe.

This case presents utilizing the Big Data techniques to calculate Calc_HK, which highlights the

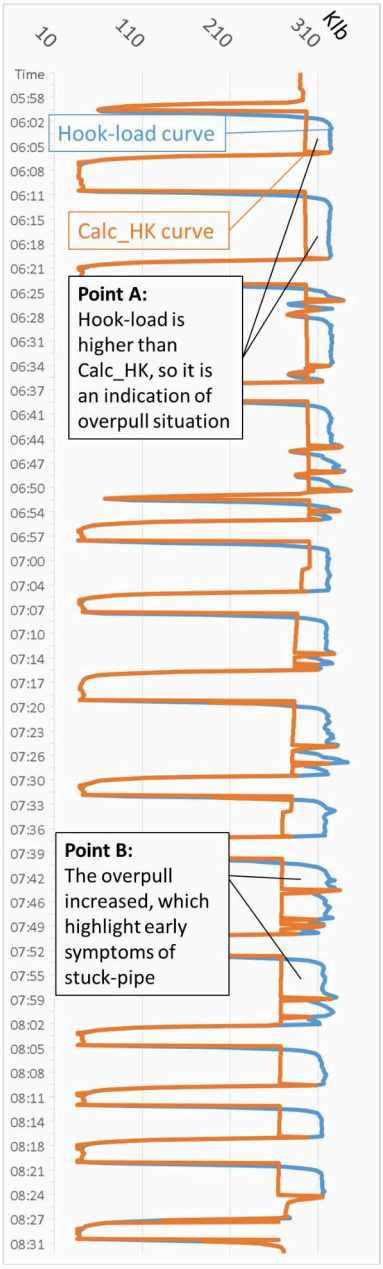

Figure 2 – Analyze Hook Load to Identify Overpull Incidents

overpull in an early stage, providing the operation crew with a bigger window to resolve the situation before it develops into a stuck-pipe problem. It is worth mentioning that using Calc_HK indicated an overpull situation +2 hours compared to a traditional monitoring process.

C. Kick Detection

An unexpected "kick" during drilling operations occurs when pressure from fluids below the drill bit exceeded the pressure in the borehole above the drill bit. They usually happen in a short period of time. A kick must be handled safely in order to prevent a potentially major accident.

Big Data techniques can be used to help with this well control problem by providing comprehensive analysis to identify the risk of a kick. We used surface drilling parameters to look for patterns identifying a kick early. Readings from Logging While Drilling (LWD) can identify changes for gas flow which contribute to a kick.

This analysis gives early signs of drilling trouble to crews and gives them a bigger window to mitigate and resolve the problem before it becomes a serious issue.

V. PROBLEMS WHEN DEALING WITH DRILLING & WORKOVER RELATED BIG DATA PROJECT

Dealing with Big Data technology is promising but there are challenges one must be willing to overcome. The biggest challenges are related to the Data which has been gathered over time and will be the source of all the information uncovered during analysis.

A. Data Preparation

Large enterprises want to leverage the data they have collected for insights during a Big Data project. The richer and more complete the input data set, the more reliable and better the analysis, and the more trustworthy the results are.

Special attention must be given to data preparation. Before starting a Big Data project, one must carefully study the input data for following factors:

1) Data Types

Data collected over time can be in different data sets and in different formats. Each of these differnt types of data will need to be combined in a single format so that they can be analyzed together. Therefore, ensure that data migration tools used for a Big Data project can handle the different data types you are dealing with.

2) Data Standards

Data may have been collected by different service companies, and may reside in different formats. To make it more complicated, when dealing with enterprise level data collected over years, standards may have changed over time also. So it is important to plan for all the different formats you may deal with in your study.

3) Data Quality

The better the quality, integrity, and completeness of the input data, the better the analysis, results and conclusions based on it.

As the old idiom goes: Garbage In Garbage Out. Advanced analytics based on erroneous data can lead to creating incorrect models and profiles; and subsequently using these models to make predictions can be prone to error. It is not possible to have 100% accurate, quality checked data when dealing with large volumes of data involved in a Big Data project. One must be aware of the quality and margin of error so that it can be taken into account when publishing results.

In summary, data preparation includes identifying the input data, checking the different sources that provided the data, being aware of the various formats it can be in, and assessing the quality of data one is dealing with.

"Advanced analytics based on erroneous data can lead to creating incorrect models "

B. Subject Matter Experts

Applying Big Data technology to operations such as those described in this paper cannot be done without the time and input from users who are experts in their areas. They are key to providing the business factors which should be considered, and validating any correlations or findings that machines generate. When embarking on such a project, it is imperative to plan for this, and budget their time into the project. The time for subject matter experts is not always easy to get, and given the nature of a Big Data project which involves some degree of trial and error, one must be careful to use the time wisely.

C. Time Factor

The turnaround time for obtaining the results depends on the business case. For on-going drilling operations, results are needed quickly. One wants to predict the kick "before" it occurs. Other business cases may not need a fast turnaround time. During real-time operations one must assess the infrastructure and tools used for Big Data in order to meet the business objective.

D. Remote Locations

When dealing with Drilling & Workover, it is necessary to consider that data processing may be distributed across sites. Some data is on the rig site, while other data may be available in database in the head office. Therefore, the architecture needed to support such a business case must take into account strong network links, and local and remote data analysis capabilities.

E. Data Security

A Big Data project requires performing analysis on a large data set. The richer the data set, the more facts considered during analysis, and the more reliable the results are. This gives rise to data security issues which may occur and should be dealt with when planning such a project. In the case of Drilling and Workover analysis requiring geological data and data from offset wells, ensure that you have the necessary access. If the access for geology or data from offset wells is not available, then the analysis will yield poor results.

VI. CONCLUSION AND FUTURE WORK

Big Data is a new and emerging technology. The information technology architecture needed to support the work is catching up to the business need. Key skill sets required to perform tasks such as data science, advanced understanding of statistics, and a combination of business data knowledge and technology expertise is difficult to find.

"Big Data is a new and emerging technology"

[1] IBM Inc. http://www.ibm.com/it-glossary/big-data/ , retrieved on March 10, 2014.
[2] J. Johnston & Aurelian Guichard, "Using Big Data Anlysis Tools to Understand Bad Hole Sections on the UK Continental Shelf" JPT - SPE, Sep. 06, 2015.
[3] Alsalama A, Canlas J & Gharbi S, "An Integrated System for Drilling Real Time Data Analytics ", SPE-181001-MS
[4] Gharbi S, Sanie F & Zayer M, "Automated Real time Data Cleansing and Summarization; Case Study on Drilling Hook load Real time Data", SPE-176755-MS
[5] Yami A, Shaarawi A, Bahrani H, Wagle V, Gharbi S, Khudiri M, "Using Bayesian Network to Develop Drilling Expert Systems ", SPE-184168-MS

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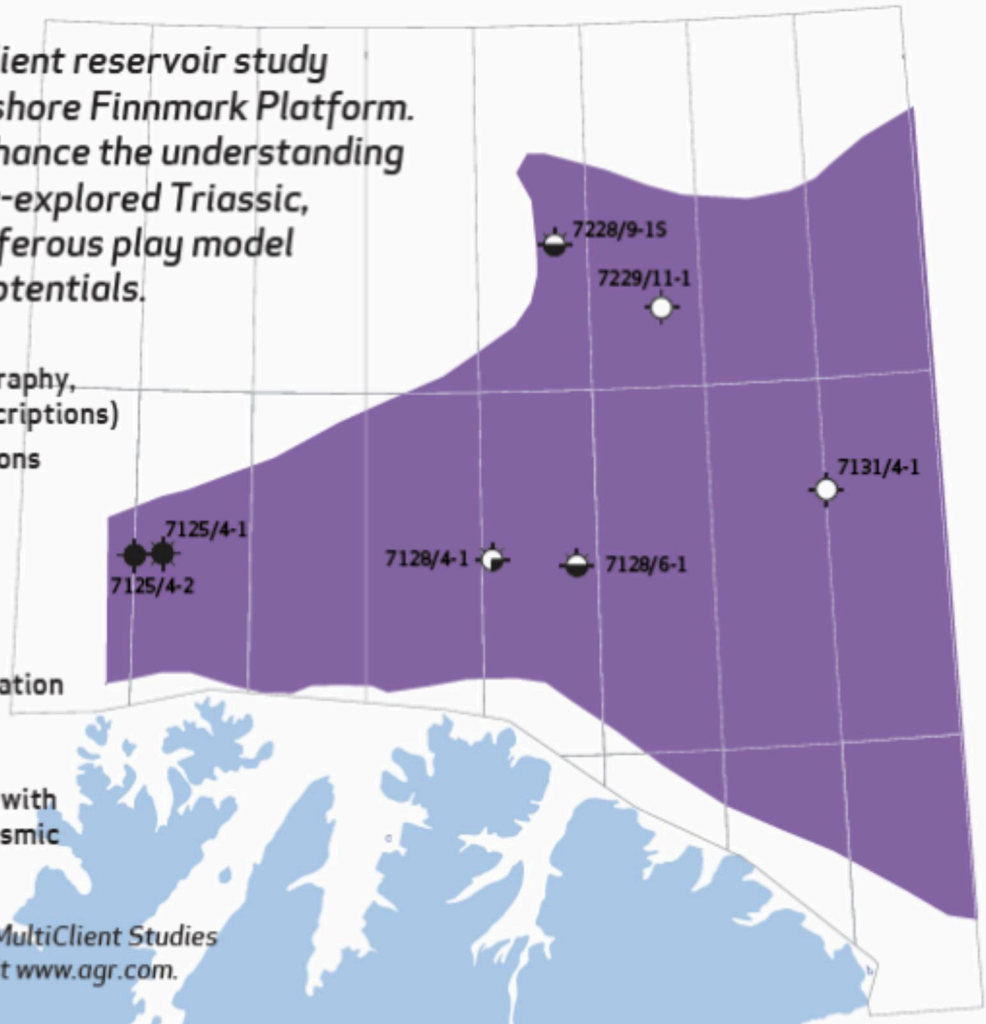

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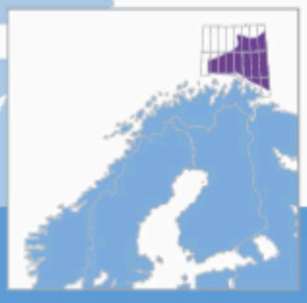

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Norwegian Ilmenite Solves Drilling Challenges & Enhancing Well Productivity

About Elkem

Elkem is one of the world's leading companies for the environmentally responsible production of materials. Its principal products are silicon, silicones, ferrosilicon, foundry alloys, carbon materials and microsilica. Elkem has four business areas and about 6100 employees.

Weight material is used to increase the density of the drilling fluid. It's an essential component to control downhole pressures. Barite has been the standard weight material for drilling fluids since the 1920's.

However, increasing challenges faced by the industry often require specialized drilling fluids. For these wells API barite may not be suitable. Thus, materials providing improved overall performance compared to API barite are required. Elkem was the first company to introduce micronized weight material to the oil and gas industry. In 1989 Elkem was granted the patent for the use of manganese tetraoxide (sold under the tradename Micromax®) as a microfine weight material for drilling and oil-well cementing fluids. Micromax has been used worldwide to drill and complete challenging wells. Over the last 20 years, Micromax® has ensured oil companies could drill wells that were not considered possible to drill with API barite.

Recently, Elkem recognized the growing need for a weight material capable of providing better fluid performance than barite and offering more added value to Operators and is less expensive than specialty weight materials. Elkem has developed an enhanced weight material that provides such a solution. This is Microdense ($FeTiO_3$). Elkem has developed Microdense with Titania, one of the largest producers of ilmenite in the world. Ilmenite is produced in huge quantities from Titania's plant in Hauge I Dalane, where more than 600 million tons of raw material is readily available, providing a low environmental footprint for the Norwegian oil and gas industry compared to other weight materials. As high-quality grade of barite resources - with a density of at least 4.20 SG - is diminishing globally, Microdense is a locally sourced weight material with no limitations of supply.

Dr. Mohamed Al-Bagoury
Scientific Advisor – Product Champion, Elkem Silicon Materials

metals. Microdense is classified as a "green" product and is PLONOR listed.

The Elkem oilfield laboratory in Kristiansand, Norway has extensively tested Microdense in a wide variety of applications in non-aqueous and aqueous drilling fluids, spacer fluids and for oil-well cementing, of which some results are shown in this paper.

Microdense provides the operator with the following benefits:
1) Significant reduction in the non-productive time (NPT) by minimizing drilling challenges such as stuck pipe and barite sag. Comparing Microdense to API barite fluids, the Microdense fluids provide a reduction in ECD values thus lower the risks of fracturing pressure-sensitive formation hence losses to the formation and wellbore instability. These challenges create risks and the inability to complete a well.
2) Reduce operational time (OPT) by lowering overall fluid viscosity,

"The Elkem oilfield laboratory in Kristiansand, Norway has extensively tested Microdense in a wide variety of applications"

Microdense® patented technology produces a 5µm material taken from well selected ilmenite ores. The production goes through several milling and refining processes. The unique technical features of Microdense, such as high density, micro-round particles, high hardness, less abrasiveness and acid solubility make it an optimal weight material for drilling and cementing fluids. Microdense has an improved environmental profile compared to API barite as it contains fewer heavy

thereby lowering frictional forces and associated challenges from such.
3) Higher rate of penetration (ROP) due to the improved hydraulics provided by the drilling fluid. This is due to the Microdense exhibiting a very small, narrow size particle distribution with a density of 4.6 SG – which again leads to fewer solids in the drilling fluids system as compared to API barite. These features allow lower viscosity fluids to be used, without compromising sag, with improved hydraulics as the outcome.

Ole Iacob Prebensen
Global Marketing Manager
Elkem Silicon Materials – Oilfield

6) Lower gel structure and fluid viscosity reduce swab and surge pressures, leading to reduced tripping time, resulting in cost savings for the Operator.
7) Enhanced logistics and powder handling, since Microdense - unlike micronized barite - is pneumatically conveyable. This saves time and money compared to handling of big bags and dealing with spike fluids, allowing safer operations.
8) Microdense fluids exhibit high return permeabilities leading to higher productivity. Its acid solubility enhances production, allowing this weight material to be used in the reservoir section.
9) Improved environmental profile as Microdense contains less heavy metals compared to API barite.
In this paper examples of testing and usage of Microdense in drilling fluids are presented. Acid solubility of Microdense will also be discussed.

Experiments & Materials
Micronized ilmenite

"Microdense fluids exhibit high return permeabilities leading to higher productivity"

4) Unlike API barite, Microdense particles resist mechanical degradation due to its hardness. Degradation of API barite leads to fluid deterioration hence increasing dumping and dilution. Microdense will extend the longevity of the fluid as the amount of disposed drilling fluids and associated cost is reduced.
5) Permits higher flow rates due to lower and improved rheological properties. As an outcome improved hole cleaning is obtained, allowing operational time savings.

A well selected area of ilmenite quality ores is used in this work. These ilmenite ores go into several processing steps by means of crushing, milling and refining to gain the micronized $FeTiO_3$. To assure highly quality product, standardized characterization methods such as particle size, specific gravity, magnetite content are in place.

Figure 2 show the particle size distribution of milled ilmenite measured using laser diffraction using

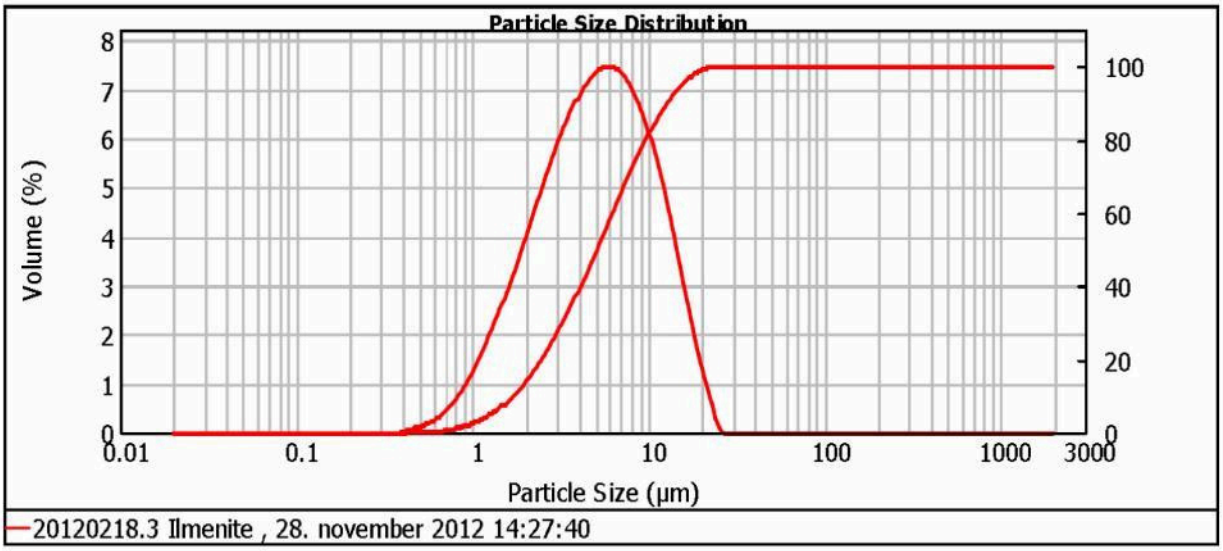

Figure 2: Particle size distribution of milled ilmenite (D10=1.7µm, D50=5µm & D90=12.6µm).

Test Results	Unit	Microdense		API Barite	
		Before Hot Rolling	After Hot Rolling	Before Hot Rolling	After Hot Rolling
Density	SG	1.92	1.92	1.92	1.92
Plastic Viscosity	cP	23	25	34	36
Yield Point	lb/100ft²	5	5	8	1
Gel Strength 10 sec.	lb/100ft²	3	3	5	2
Gel Strength 10 min.	lb/100ft²	5	6	13	5
VSST	ppg	0.150	0.308	0.250	0.500
Filter Cake Thickness	inch	0.23	0.27	0.20	0.23
Volume of Filtrate	cm³	3.1	3.5	1.7	2.2

Table 1: Properties of 1.92 SG non-aqueous fluid that heat aged at 204˚C for 16 hours.

a refractive index of 2.8. The average size (D50) is 5µm and the D90 is less than 13µm.

The mineralogical composition of the ilmenite sample was analyzed using the X-ray diffraction (XRD). Microdense is mainly composed of (FeO, MgO) TiO2 (> 94 percent by weight).

The material also contains < 3 percent by weight silicate phases such as orthopyroxene (Mg, Fe) SiO3, plagioclase

((NaAlSi3O8)(CaAl2Si2O8)), and biotite. The morphology of Microdense was studied using scanning electron microscope and particle imaging analyzer. The material has a high circularity of > 0.85, which contributes to lowering the viscosity of its dispersions. The total specific surface area of 1.6 m2/g was measured by the Brunauer-Emmett-Teller (BET) method.

Use of Microdense in drilling fluids

Below are examples of the use of Microdense as weight material in both aqueous and non-aqueous drilling fluids. High density fluids (1.6 - 2.3SG) with a high loading of weighting agents were selected to demonstrate the enhanced properties from this weighing agent.

Microdense – laboratory testing in non-aqueous drilling fluids

The papers SPE165184 & SPE 155331 reported the extensive laboratory testing of Microdense in non-aqueous drilling fluid. The performance of Microdense was compared with other weight materials such as API barite and Micromax. The main conclusions and recommendations of testing Microdense in oil based system were as follows;

1. Microdense can be successfully used as a weight material in aqueous and non-aqueous drilling fluids in a wide density range, and is well suited for conventional and challenging drilling operations.
2. The specific surface area and the fineness of micronized material should be taken into consideration when formulating new fluids. Generally, Microdense requires less amount of viscosifier to be suspended. For dispersion purposes, slightly more dispersant and wetting agent is needed when compared to API barite.
3. Microdense fluids show good filtration properties using organophilic lignite - with or without synthetic polymer such as styrene-butadiene polymer. A thin filter cake and a small filtrate volume were obtained under static and dynamic conditions at 150°C and 500 psi.
4. Microdense shows low dynamic sag (< 0.3), which makes it suitable for challenging drilling operations such as HPHT, narrow pressure margin drilling and extended reach wells.
5. This weight material provided very lower plastic viscosities (PV) compared to API Barite.

"Microdense fluids show good filtration properties using organophilic lignite"

As an example (Table 1) properties of two drilling fluids are listed, one weighted with Microdense and another with API barite. The plastic viscosity and dynamic sag (VSST) for Microdense is significantly lower than for API barite. Even if it can be challenging to control filtration loss for fine and monomodal particle size distribution, the dynamic filtration was

“Microdense has been tested at ultra-high densities”

in the acceptable range (<5ml) for Microdense fluid. Added particles in the form of sized Calcium Carbonate or any other wellbore strengthening material have not been used in the fluid formulation to assist in the fluid loss.

Microdense has been tested at ultra-high densities. In Table 2 a 2.30 SG non-aqueous fluid with Microdense was heat aged at 200°C for 64 hours, whereas in the second fluid a 2.20 SG with a mixture of Microdense (23%) and API Barite (77%) was tested and heat aged at 175°C for 16 hours.

Both fluids exhibit low rheological properties with non-progressive gel structure, minimal sag potential and good electrical stability. Still the Microdense stand-alone fluid at 2.30 SG outperforms the mixed weighting agent fluid at 2.20 SG, with excellent plastic viscosity, hence low high-end readings, even at higher density. Fluid loss at 175°C and filter cake thickness is regarded as very good. Microdense allows for cost efficient low viscous fluids, and sag resistance.

Testing Microdense and comparing this proprietary product to API barite at more conventional densities like 1.60 SG shows similar properties; lower high-end values and similar low-end readings, all of which contribute to added values to Operators as listed above.

Test Results	Unit	Microdense Heat aged 200°C 64 hours		23% Microdense, 77% Barite Heat aged at 175°C for 16 hours	
		Before Heat Ageing	After Heat Ageing	Before Heat Ageing	After Heat Ageing
Density	SG	2.30	2.30	2.20	2.20
600 rpm	lb/100ft²	82	88	96	100
300 rpm	lb/100ft²	42	47	54	55
200 rpm	lb/100ft²	28	33	40	39
100 rpm	lb/100ft²	16	20	26	24
6 rpm	lb/100ft²	3	7	8	6
3 rpm	lb/100ft²	2	6	7	5
Gel Strength 10 sec.	lb/100ft²	3	7	8	7
Gel Strength 10 min.	lb/100ft²	3	10	9	13
Plastic Viscosity	cP	40	41	42	45
Yield Point	lb/100ft²	2	6	12	10
Fluid loss at 175°C	ml/s	4	4.5	4	4
Filter cake	mm	1	1	2	3
Static Sag		-	0.519	-	0.505
Electrical Stability	mV	435	621	728	878

Table 2: Properties of 2.30 SG and 2.20 SG non-aqueous fluids

Test Results	Unit	Microdense Heat aged 150°C 16 hours		Barite Heat aged at 150°C for 16 hours	
		Before Heat Ageing	After Heat Ageing	Before Heat Ageing	After Heat Ageing
Density	SG	2.10	2.10	2.10	2.10
600 rpm	lb/100ft²	100	98	125	156
300 rpm	lb/100ft²	54	53	70	87
200 rpm	lb/100ft²	41	40	51	62
100 rpm	lb/100ft²	23	21	27	34
6 rpm	lb/100ft²	6	4	5	5
3 rpm	lb/100ft²	5	3	4	4
Gel Strength 10 sec.	lb/100ft²	5	3	5	4
Gel Strength 10 min.	lb/100ft²	8	5	5	7
Plastic Viscosity	cP	46	45	55	69
Yield Point	lb/100ft²	8	8	15	18
Sag Factor	-	-	0.520	-	0.530

Table 3: Properties of 2.10 aqueous drilling fluids

"The contribution from Microdense will ensure less non-productive time"

Using Microdense as the weighting agent at these densities will enable Operators to obtain lower pump pressures for the same flow rate as for API barite, and lower the ECD values. These features should contribute to reduce downhole losses, increase tripping speeds due to the nature of the rheological properties, and if needed; obtain the same ECD with increased flow rate. The latter will assist in improved hole cleaning.

In general, the contribution from Microdense will ensure less non-productive time (NPT) and thereby contribute to reduced overall operational cost for the Operators.

Microdense – laboratory testing in aqueous drilling fluids

So, is Microdense suitable for aqueous drilling fluid? Test results at 2.10 SG provides the same overall results as for non-aqueous drilling fluids with regards to fluid properties. As shown in Table 3, the rheological properties exhibit the same trendline with very low PV values for Microdense, at similar low-end readings. Even if YP values are reduced and low-end values are low, the buoyancy of the fluid will greatly assist in hole cleaning at this density, thus these values are of low interest.

Microdense in aqueous kill fluid

Test Results	Unit	Micromax / Microdense Kill Fluid Heat aged 80°C 16 hours		Micromax / Microdense Kill Fluid Heat aged 80°C 16 hours		Micromax / Microdense Kill Fluid Heat aged 80°C 16 hours	
		Before Heat Ageing	After Heat Ageing	Before Heat Ageing	After Heat Ageing	Before Heat Ageing	After Heat Ageing
Density	SG	2.50	2.50	2.75	2.75	3.00	3.00
600 rpm	lb/100ft²	82	68	123	101	230	184
300 rpm	lb/100ft²	45	39	68	56	121	100
200 rpm	lb/100ft²	32	29	48	40	84	69
100 rpm	lb/100ft²	18	18	29	24	47	40
6 rpm	lb/100ft²	3	7	7	8	9	10
3 rpm	lb/100ft²	2	6	5	6	8	8
Gel Strength 10 sec.	lb/100ft²	3	6	5	6	10	9
Gel Strength 10 min.	lb/100ft²	4	7	13	8	29	21
Plastic Viscosity	cP	37	29	55	45	109	84
Yield Point	lb/100ft²	8	10	13	11	12	16
HPHT Fluid Loss	mls	11.6	10	15	6	10	8.5

Table 5: Properties of 2.50 – 3.00 SG Micromax / Microdense Kill Fluid in sodium chloride brine.

"The high-density kill fluid met the Operators requirements, showing the feasibility of the Microdense at extreme densities"

An Operator requested a kill fluid at extreme density of 3.00 SG, with low viscosity to be used in a gas field. Previously API barite was used up to 2.24 SG, but above this density it became very viscous and un-pumpable. A series of tests were conducted in a simple fluid formulation with a low-viscosity modified starch, an acrylic based HPHT dispersant in a saturated sodium chloride brine solution using 50 /50 mixture of Microdense and Micromax as weight materials. . The concentration of starch was kept constant, regardless of density. The bottom hole temperature was below 100°C, allowing heat ageing to be performed at 80°C. The desired fluid properties are highlighted in Table 5:

The high-density kill fluid met the Operators requirements, showing the feasibility of the Microdense at extreme densities. This mixture of weight materials provided the Operator with a suitable kill fluid, that was regarded as a cost-efficient solution.

Ilmenite solubility in HCl

The solubility of ilmenite in mineral acids such as sulphuric (H_2SO_4) or hydrochloric (HCl) acids is a widely used industrial process to gain titanium dioxide pigment. The solubility of ilmenite is extensively studied in literature. The dissolution mechanism of ilmenite in HCl can be drawn as follows:

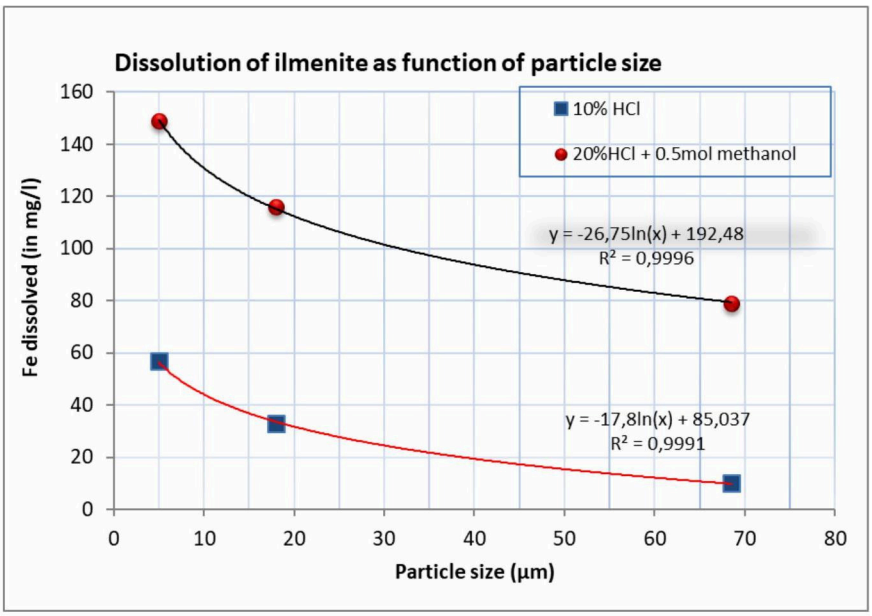

Figure 3: Dissolution of ilmenite as function of particle size

"This high dissolution rate is of great advantage when acidizing is considered"

$FeTiO_3 + 4\ HCl \rightarrow TiOCl_2 + FeCl_2 + 2H_2O$

Since HCl is commonly used in stimulation, the solubility of Microdense in HCl was investigated under various conditions of acid concentrations and temperatures. It was found that Microdense has an improved rate of dissolution compared to the coarser ilmenite grades used in the past. The higher the acid concentration and /or the higher the temperature, the higher the dissolution rate of ilmenite. Figure 3 show the dissolution of Fe ion in HCl at 82˚C as a function of particle size. The reaction was monitored by Inductively Coupled Plasma (ICP) technique. The dissolution of ilmenite is a power function of particle size. This high dissolution rate is of great advantage when acidizing is considered.

Case Histories:

A Middle East operator was drilling extended reach development wells to increase production. The Operator had previously faced serious torque and drag problems combined with high friction factors, high ECD's and downhole losses. Consequently, this Operator was unable to drill the 8.5in. hole past 7620 mMD to achieve the desired higher production rate.

The Operator was looking for a reservoir drilling fluid that would

increase the horizontal lengths to maximize reservoir contact, reduce torque and drag and reduce ECD to avoid heavy losses. The fluid needed to be non-damaging and remediable.

A non-damaging Microdense non-aqueous reservoir drilling fluid (RDF) was field trialed. The Operator drilled these wells to a new record of 9420 mMD without any fluid related or operational problems. Rate of penetration was improved by 25% compared to offset wells, friction reduction of at least 100% were obtained, and has been one of the key developments in being able to drill and complete these extended laterals.

allowing the Operator to achieve the strategic goal of increasing production rate by around 40% in total from this field development. The success of this project has resulted in the operator extending the project for a further six years.

A second Operator used Microdense at ultra-high density in a sodium chloride polymer drilling fluid. This well encountered high pressures zones, requiring an unplanned density increase from 1.71 SG to 2.35 SG. The Operators drivers for using Microdense were; reduce solids content, the ability of Microdense to be acidizable in the occurrence of stuck

"Microdense is a very efficient weight material for drilling conventional, technically challenging and expensive wells"

Losses to the formation were dramatically reduced; all of which saving three days per well on average versus offset wells excluding NPT. Average flow rates were increased from 1500 lpm to 1800 lpm allowing improved hole cleaning and smooth tripping operations. The Operator reported that the actual deployment of the 6 5/8" lower completion was excellent, requiring no rotation of the drillpipe running string as the friction factors were dramatically reduced in this record length well. This was accomplished by the lubricious non-aqueous RDF and good hole cleaning after reaching total depth.

Due to the extended reach of the reservoir sections, these wells have increased production rate by close to 100% compared to previous wells,

pipe, to reduce ECD, and to enable higher density increase compared to API barite - still maintaining fluid specifications. Despite the unplanned increase in density, all properties were maintained and the well successfully drilled to total depth. These applications of Microdense illustrates the value of using this non-damaging and novel weigh material.

Conclusion:

Microdense is a very efficient weight material for drilling conventional, technically challenging and expensive wells, providing great value and cost savings to Operators. Microdense contributes in reducing non-productive time through eliminating drilling problems such as downhole losses, stuck pipe, sag, and enhances

The acid solubility of Microdense increases productivity. Furthermore, the pneumatic conveyance of Microdense is a great benefit for offshore applications compared to other specialty or micronized weight materials. Thus, this Norwegian produced weight material exhibits unique value and an environmental classification well suited for the Norwegian Continental Shelf.

Acknowledgments

The authors would like to thank Elkem AS for permission to publish this paper.

"Norwegian produced weight material exhibits unique value and an environmental classification"

1. Al-Bagoury M. and Steele C., Oil well drilling fluids, oil well cement composition, and slurry of weighting material comprising ilmenite, patent WO2013009187.

2. Al-Bagoury M. and Steele C., A New, Alternative Weight Material for Drilling Fluids, SPE-151331.

3. Al-Bagoury M., Micronized Ilmenite - A Non-Damaging Non-Sagging New Weight material for Drilling Fluids, SPE-169182.

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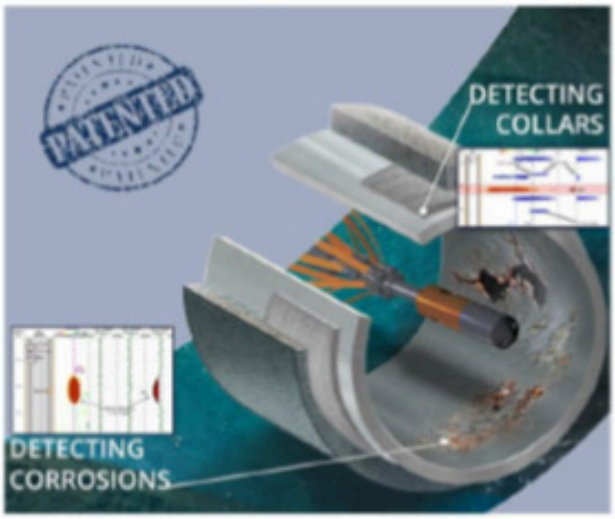

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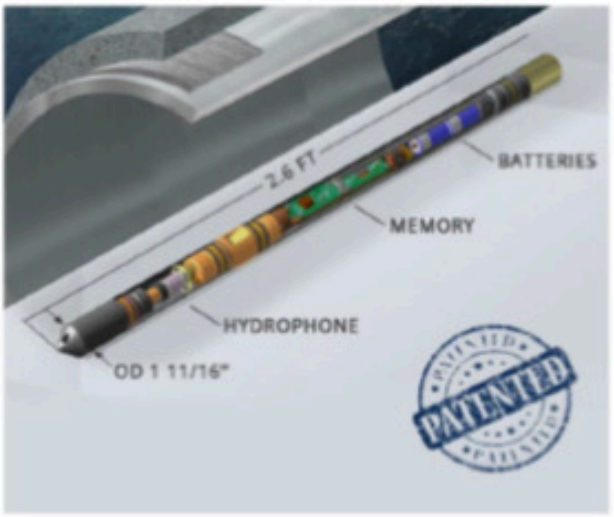

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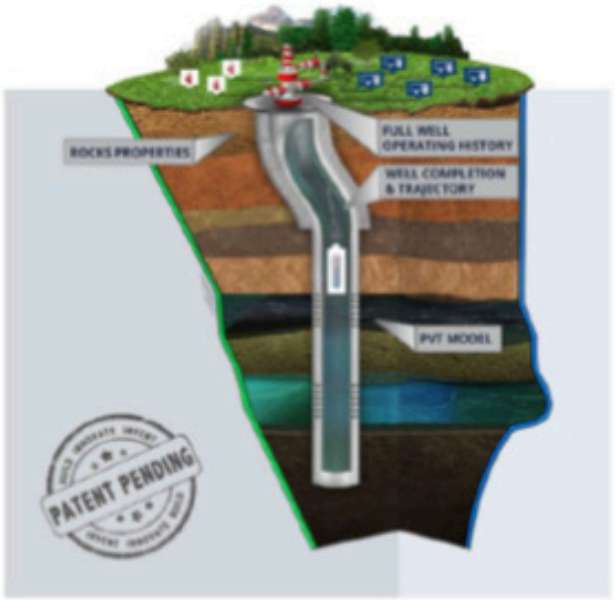

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Hole Cleaning Performance of Oil Based and Water Based Drilling Fluids – An Experimental Comparison

Transporting cuttings out of the wellbore is an important part of every drilling operation to ensure efficiency and the reduction of non-productive time. The drilling fluids used for this task are complex fluid systems, generally with either oil or water as a base substance. The hole-cleaning performance of these two fluid

"An extensive experimental study was performed to enlighten the understanding of drilling fluid performance."

systems is reportedly different from each other. Industry experience indicates that oil-based drilling fluids are performing better than water-based drilling fluids, even when the viscosity is similar. Earlier research results from the 1990s show diverse conclusions with superior behavior for either water-based or oil-based fluids, or findings where neither of the types excelled (Hareland et al., 1993; Pilehvari et al., 1995; Saasen and Løklingholm, 2002). General conclusions have not been made and the reasons for the different behavior are not entirely understood. Drilling fluids are complex fluid systems, exhibiting properties such as yield stress, thixotropy, gel strength and viscoelasticity. These properties can be measured using viscometers and rheometers, and can give insights into their low shear flow behavior.

An extensive experimental study was performed to enlighten the understanding of drilling fluid performance by comparing hole cleaning in the laboratory with the use of field applied drilling fluids from the North Sea area. The approach was to connect the viscoelastic properties with the flow and cuttings-removal properties of drilling fluids. The viscoelastic properties were measured with an Anton Paar MCR (modular compact rheometer) and the cuttings-removal properties with a flow loop. The flow loop (Figure 1) consisted of a 10 m long test section with a fully eccentric, free whirling drill string, a separation unit and several pressure cells. The oil-based drilling fluid (OBM, also referred to as OBM B) of the study is an oil-in-water emulsion containing barite, $CaCl_2$, bentonite, lime, emulsifier and a fluid loss agent. The water-based fluid (WBM) is a KCl/polymer based drilling fluid with glycol, xanthan gum, polyanionic cellulose, starch, soda ash and barite. The densities are 1.26 g/cm3 and 1.19 g/cm3 respectively.

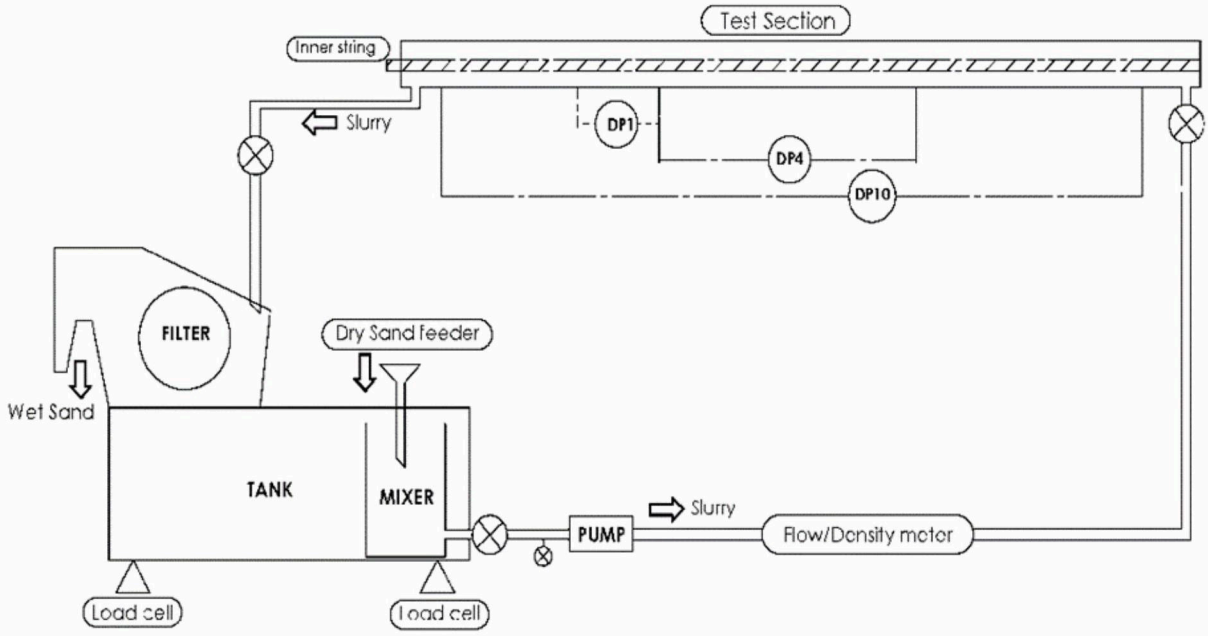

Figure 1. Flow loop setup

"It is also important to improve models for the estimation of cuttings transport"

Results

The comparative cuttings transport study of an oil-based and a water-based fluid with similar viscosity profiles supports the industrial experience that oil-based drilling fluids perform better than water-based drilling fluids. In Figure 4 it is observed that, without drill-string rotation, a significant difference in the hole-cleaning performance of the two drilling fluids occurs. In the absence of drill-string rotation, hole-cleaning performance was significantly better using the oil-based drilling fluid than water-based drilling fluid. For high drill-string rotation rate, the hole-cleaning performance of the water-based drilling fluid approaches that of the oil-based drilling fluid. This knowledge will be helpful in selection of fluids when planning the well construction. It is also important to improve models for the estimation of cuttings transport and this is important for further digitalization of the field operations. Undoubtedly, drill-string rotation has a significant positive effect on cuttings transport. However, drill-string rotation had a greater effect on water-based drilling fluid as compared to oil-based drilling fluid.

The viscoelastic properties were found to rather influence the cutting beds resistance to erosion, instead of affecting the cuttings transport itself. An about 100 times higher strain

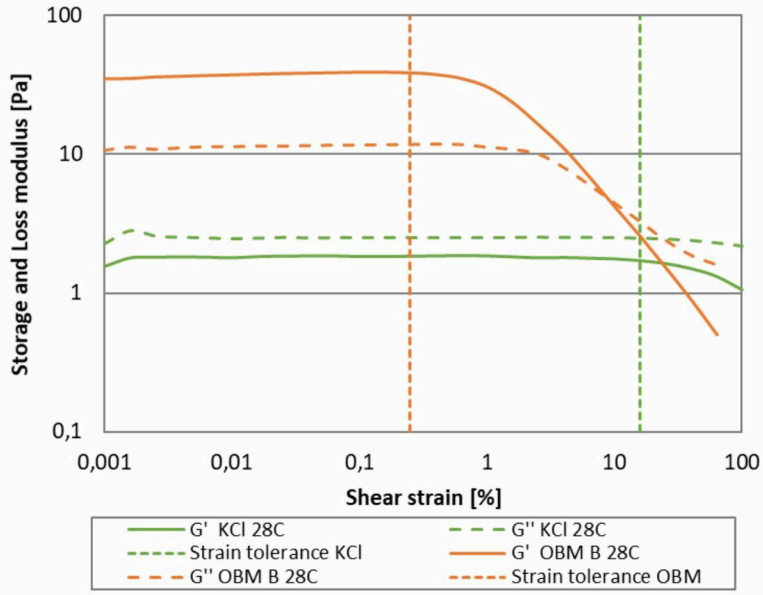

Figure 2. Amplitude sweeps showing the storage and loss moduli of the KCl fluid and the OBM B fluid for temperatures of 28 °C, measured with Anton Paar MCR 302. (data adopted from Werner et al. (2017))

"Lorem ipsum dolor sit amet, si dici consecte tuer adipisci elit integre."

tolerance was found for the KCl/ polymer fluid in amplitude-sweep tests, compared to the OBM (see dashed vertical lines in Figure 2). This higher elasticity increased the cuttings-bed resistance to erosion and created a stronger connection between the cuttings particles. Comparably, the yield stress in the OBM was broken more easily than the elasticity in the KCl fluid, leading to more efficient hole cleaning for OBM B compared to the KCl fluid. However, the storage module (G') in the OBM is about 30 times higher than in the KCl/polymer fluid (see Figure 2). The storage module describes the stored deformation energy in the fluid and is likely to illustrate the apparent yield stress of the fluids.

Figure 3 shows estimated shear rates for various standard borehole sizes and drill-string sizes used in the industry. The relevant shear rate range for the fluids during drilling is in the lower range. The shear rates would still be lower in the presence of a cuttings bed. Typical viscosity models created using the 300 and 600 RPM (511 and 1022 1/s) reading of the VG meter is, by far, outside the correct shear rate range for flow in annuli. Exceptions are flow along the BHA. For flow along the drill pipe the maximum shear rates are in the range as indicated in Figure 3. To be able to correctly estimate the drilling fluid hydraulics and hole cleaning, it is necessary to interpolate viscometer data from the relevant

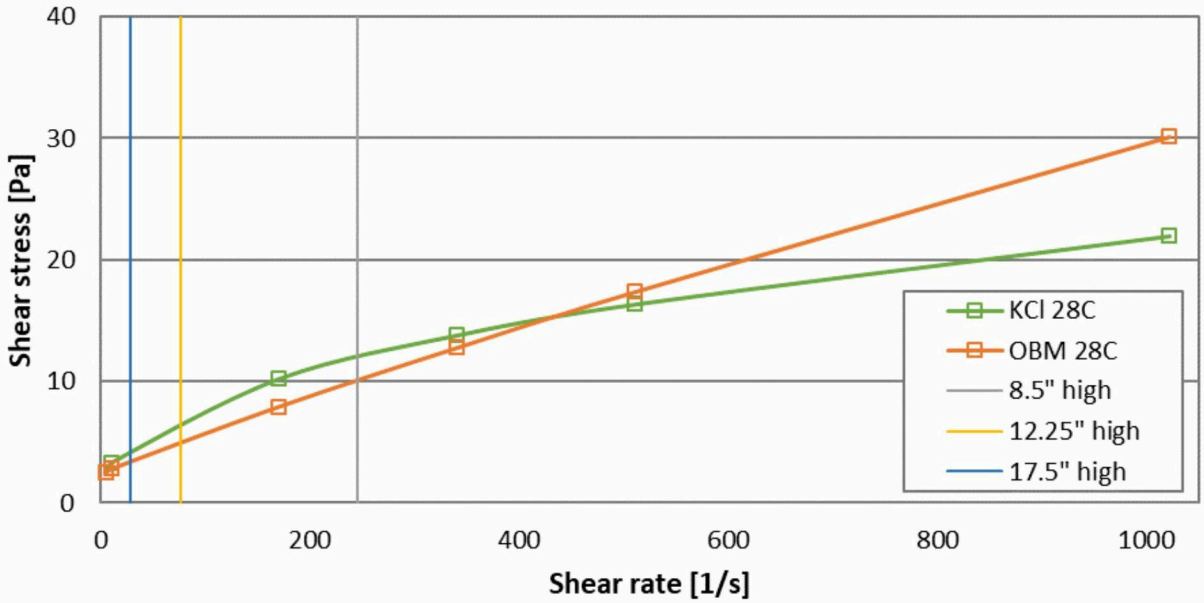

Figure 3. Fann 35 measurements of the KCl fluid and OBM B at 28 °C together with typical maximum shear rates for common borehole sizes. (data adopted from Werner et al. (2017))

"The oil–based drilling fluid used in this study showed a superior cuttings-transport ability"

shear rate to create realistic viscosity predictions independent on the type of applied model.

A CFD model of the horizontal annulus was developed and validated against the flow loop experimental data and data from the literature. The developed CFD model predicts, with acceptable accuracy, the frictional pressure loss in laminar and turbulent flow of non-Newtonian fluid for liquid flow through in horizontal annulus with and without drill string rotation.

Conclusion

An oil-based and a water-based drilling fluid have been compared regarding their rheological properties and their hole-cleaning capabilities. The characterization was done with an Anton Paar rheometer measuring viscoelastic properties. Hole-cleaning capabilities were investigated with flow-loop experiments. The oil-based drilling fluid used in this study showed a superior cuttings-transport ability to the water-based drilling fluid in the presence of drill string rotation. However, cuttings-transport ability of both the fluids was nearly the same in the absence of drill string rotation. The rheological characterization of the tested fluids provided insights into their viscoelastic behavior. The results suggest particle and emulsion based fluids, exhibiting light internal structures at low shear rates and small

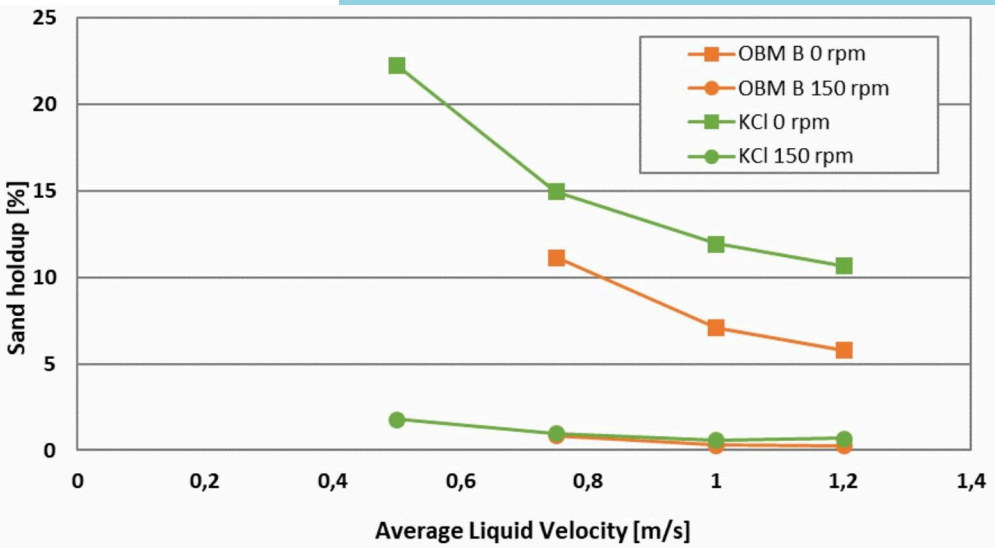

Figure 4 Sand holdup versus superficial liquid velocity for the KCl fluid and OBM B with and without drill-string rotation. (data adopted from Sayindla et al. (2017b))

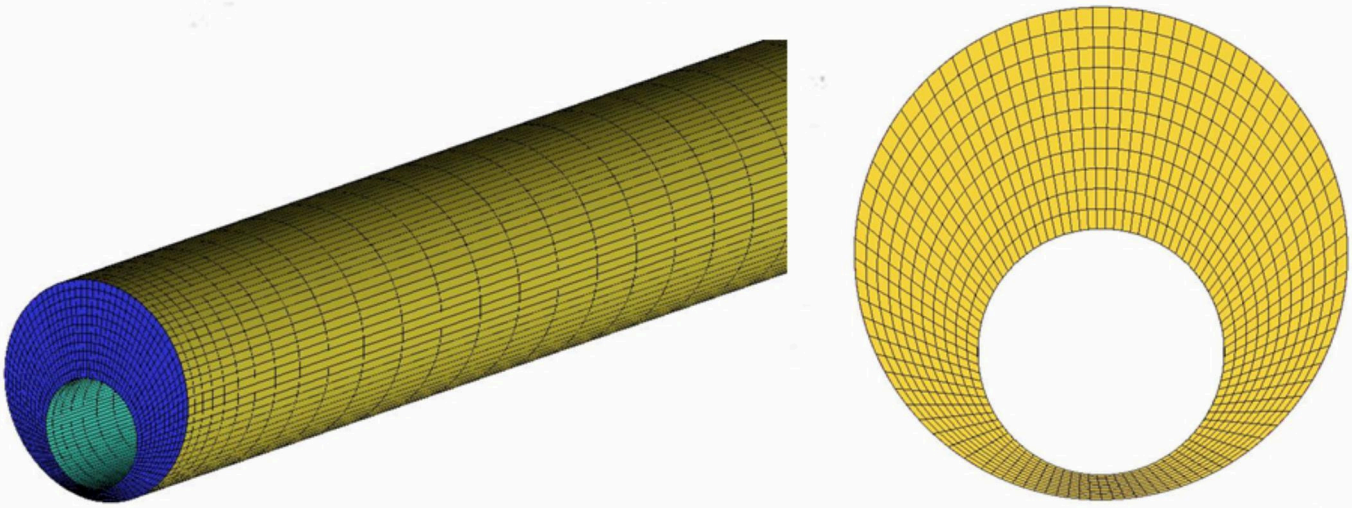

Figure 5 Annulus geometry and computational mesh. (adopted from Sayindla et al. (2017a))

yield stresses being the better option for hole cleaning. This is most likely due to a better suspension capability of the cuttings in the fluid during flow, and due to the absence of polymers consolidating the cutting beds that make these beds difficult to remove.

References:

Hareland, G., Azar, J.J. and Rampesad, P.R., 1993. Comparison of Cuttings Transport in Directional Drilling Using Low-Toxicity Invert Emulsion Mineral-Oil-Based and Water-Based Muds, SPE Rocky Mountain Regional/Low Permeability Reservoirs Symposium, Denver, Colorado.

Pilehvari, A.A., Azar, J.J. and Shirazi, S.A., 1995. State-Of-The-Art Cuttings Transport in Horizontal Wellbores, SPE International Conference on Horizontal Well Technology, Calgary, Canada.

Saasen, A. and Løklingholm, G., 2002. The Effect of Drilling Fluid Rheological Properties on Hole Cleaning, IADC/ SPE Drilling Conference, Dallas, TX, USA

Sayindla, S., Lund, B., Ytrehus, J.D. and Saasen, A., 2017a. CFD Modelling of Observed Cuttings Transport in Oil-Based and Water-Based Drilling Fluids. SPE/IADC Drilling Conference and Exhibition.

Sayindla, S., Lund, B., Ytrehus, J.D. and Saasen, A., 2017b. Hole-cleaning performance comparison of oil-based and water-based drilling fluids. Journal of Petroleum Science and Engineering, 159: 49 - 57.

Werner, B., Myrseth, V. and Saasen, A., 2017. Viscoelastic properties of drilling fluids and their influence on cuttings transport. Journal of Petroleum Science and Engineering, 156: 845 -851.

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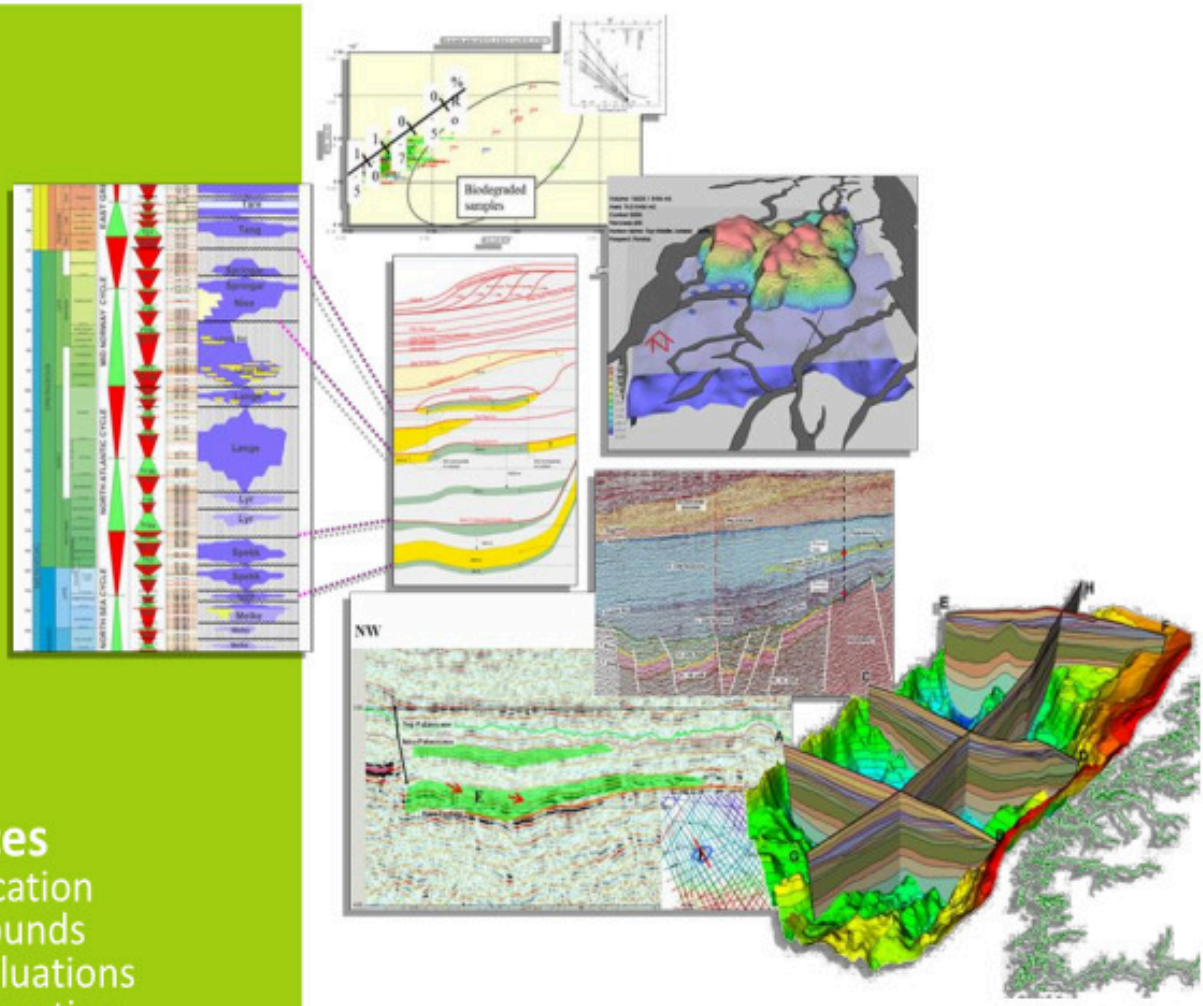

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