THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF ENERGY AND MINERAL ENGINEERING

EXPERIMENTAL EVALUATION OF THE IMPACT OF OIL-BASED MUD RESIDUALS ON CEMENT-FORMATION BONDING STRENGTH

ANWAR SALAH S ALGHAMDI
SPRING 2019

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degrees
in Petroleum and Natural Gas Engineering and Economics
with honors in Petroleum and Natural Gas Engineering

Reviewed and approved* by the following:

Arash Dahi Taleghani
Associate Professor of Petroleum and Natural Gas Engineering
Thesis Supervisor

John Yilin Wang
Associate Professor of Petroleum and Natural Gas Engineering
Honors Adviser

* Signatures are on file in the Schreyer Honors College.

ABSTRACT

Mud removal is a key operation to ensure successful well cementing and, consequently, zonal isolation through the lifetime of the well. If mud is not properly removed, a thin layer of mud may remain in place and contaminate the cement slurry and prevent cement of strong bonding with the formation and the casing string. Without having strong bonding at cement interfaces, the annulus becomes susceptible to gas migration, especially under extreme conditions, such as hydraulic fracturing treatments, that involves large pressure fluctuations. Oil based muds (OBMs), in comparison to water-based muds (WBMs), are improving drilling by enhancing lubricity, temperature and borehole stability, and greater penetration rates in certain formations. However, OBMs have counter effects on the cement performance by oil-wetting the formation. The objective of this work is to develop an experimental procedure to quantify the impact of wettability alteration caused by mud residuals on cement bonding in three different formations: sandstone, limestone, and shale. To this end, a modified push-out test is developed, and the effect of different OBM compositions and spacer fluids are examined.

The modified push-out setup comprises a rock-core set by cement in the center of a casing-grade steel pipe. Class-G cement slurry is prepared and placed inside the pipe and cured under high pressure and high temperature conditions of 200 °F and 3000 psi for 24 hours to mimic borehole conditions. To mimic the real conditions, the rock-cores are preconditioned with OBM for 24 hours to examine the effect of mud residues on the cement-formation rock bonding. Finally, the specimen was loaded axially at a low displacement rate of 0.3 mm/min for measuring the shear strength along the cement interfaces. Additionally, the effects of OBM oil/water ratio (OWR) and mud removal agent (spacer) on the cement-formation interface are analyzed.

Based on our findings, OBMs have negative effects on the cement-formation bonding strength inversely proportional to the OBM's OWR. While the lithology had a negligible effect on the cement performance. Therefore, higher OWR OBMs are recommended for improving cement bonding with the

casing and formation rock. In addition, a proper removal of OBM by spacer fluid increases the shear-bond strength of the cement significantly. However, the improvement is still 50% below the original shear strength measure in the absence of mud-residues. The proposed experimental setup can provide an effective tool to measure the impact of mud removal by different spacer fluids.

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ACKNOWLEDGEMENTS

This thesis is dedicated to my parents, the Chief Harbor Pilot Salah Alghamdi and Eman Alghamdi. You have always believed in and supported me. Without your support, I would have never made it to the position I am in today. I know I would never be able to pay back what you have given me, but I hope this will at least put a smile on your faces and make you proud of the man you raised. To my lovely siblings, I promise to be the role model you deserve.

I would like to express my gratitude to Dr. Arash Dahi Taleghani for giving me the chance to do my thesis with him, and believing in me and supporting me through it. I would also like to thank Dr. Amin Mehrabian, Dr. Maryam Tabatabaei and Livio Santos for guiding me throughout the research.

Lastly, much love to my fiancée, all of my professors at Penn State, teachers in school, and friends and relatives from all around the world for being in my life.

Chapter 1

Introduction

OBMs have gained popularity over the years due to excellent drilling performance achieved as compared to WBMs. In many cases, OBMs are less damaging to oil reservoirs and have better stability for clays and shales. Formation damage during drilling can substantially reduce well productivity, thus OBMs are preferred in drilling formations with sensitive clays and shales (Fjelde, 2017). In addition, drilling with OBMs in most of the time delivers better-quality boreholes than those drilling with WBMs (Salazar *et al*., 2011).

OBM has various applications in drilling, providing multiple benefits such as lubricity, temperature and borehole stability, resistance to contamination, and greater penetration rates. Consequently, OBM can noticeably affect cement performance in wellbores, and that usually happens when OBM mix with cement at well cementing after casing (Harder *et al*., 1993)

It is important to understand the composition of OBMs, and the benefits obtained through its use. OBMs are a water-in-oil (W/O) emulsion consisting of three phases, the internal phase, which is surfactant or emulsifier, the drilled solids and commercial additives. The internal phase exists as water droplets emulsified within the external oil phase. The surfactants maintain the emulsion of the water droplets to keep it stable under downhole conditions and to keep solids oil-wet within the external phase. The drilled solids and commercial additives are used to maintain required drilling properties such as yield point and plastic viscosity (Harder *et al*., 1993).

OWR is a representation of the fraction of oil and water in oil-based muds. It represents the ratio of the percent volume of oil to the percent volume of water that can be determined through a retort analysis or could be predetermined while designing a fluid mixture. The retort analysis is done when a sample of OBM is controlled burnt in a retort kit at specific temperature. Then, oil and water are extracted out from the OBM where solids are left in the retort kit to give a percentage by volume of each component and that is used to determine the OWR (Lyons et al, 2011). Furthermore, oil-in-water (O/W) emulsion is a type of emulsions where oil droplets are contained inside water, water is the external phase whereas oil is the internal phase. An example for O/W emulsion is WBMs containing oil. However, W/O emulsion is a type of emulsions where water droplets are contained inside oil, oil is the external phase and water is the internal phase. An example for W/O emulsion is OBMs (Patel and Growcock, 1999).

OBMs can also significantly affect the wettability which is an interfacial phenomenon of spreading and adhesion of fluids on a rock surface (Hirasaki, 1991). OBM residuals alter the wettability of the formation wall from water-wet to oil-wet, and since cement bonds tend to be weak to oil-wet surfaces, a poor cementing job is expected. If cementing job was not done properly, it would weaken cement bond strength between casing-cement and cement-formation interfaces that can be a great source of gas migration behind casing and sustained casing pressure build up (Michael *et al*., 2004). Prior to cementing operations, spacer fluids are typically used to pre-flush the wellbore annulus to displace the drilling fluid and prepare the well for cementing (Fig. 1). Cement slurries and drilling fluids are usually chemically incompatible; drilling fluids can contaminate cement slurries and cause various problems that will be discussed later in this work. Therefore, the drilling fluid has to be displaced from the annulus before the placement of cement slurry. This operation is generally done by pumping a spacer fluid between the drilling fluid and cement slurries to form a buffer and prevent the drilling fluid and the cement slurry from coming into contact. Since the spacer fluid is in direct contact with cement slurry and the drilling fluid in the wellbore annulus, the spacer fluid has to be compatible with both of them. Additionally, the quality of the cement job in the annulus on the long run is mainly influenced by an effective drilling fluid removal (Shadravan *et al*., 2015). In order to accomplish a good drilling mud displacement, the downhole forces implemented by the circulating fluids in the borehole have to be enough to overcome the yield stress of any partially dehydrated drilling fluids left in the hole (Ravi and Weber, 1996).

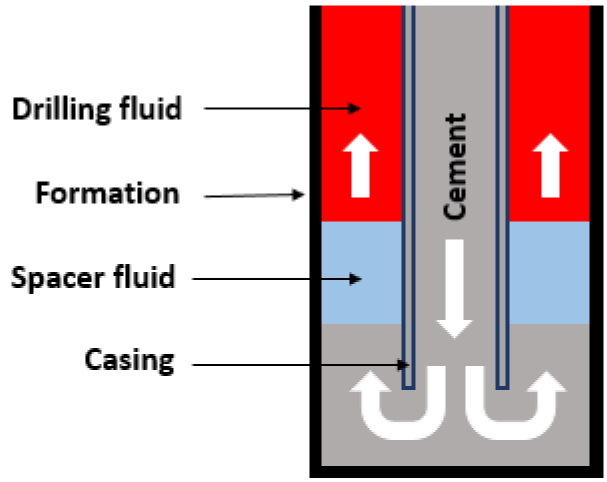

Figure 1. Schematic of drilling fluid displacement by spacer followed by cement injection

To ensure an effective cementing operation, two conditions have to be met. First, the drilling mud has to be effectively removed from the wellbore; wellbore surface and casing surfaces. Second, the formation surface has to be water-wet. Failing the first condition can cause cement contamination and affect the cement performance, where cement slurries do not bond properly with each other. Whereas failing the second condition may weaken bonding between the cement paste and the rock surface in the wellbore and casing (Ali *et al*, 2014). Spacer fluid is an aqueous water-based fluid, which comes into contact with an OBM and breaks its emulsion. The OBM has a W/O emulsion, and when it comes into contact with the spacer, the mud's emulsified water droplets absorb water until the droplets become so big that the external oil layer cannot hold them any longer, breaking the emulsion and water-wetting the mixture. Formation wall wettability plays a critical role in cementing quality. Cement slurries do not bond effectively to oil-wet surfaces. Therefore, spacer is used to water-wet the formation right after an OBM was used (Patel *et al*., 1999).

The objective of this research is to experimentally evaluate the impact of OBM residuals on cement bonding to the formation rock, and how spacer is effective in displacing those residuals and improving cement bonding. To this end, a modified push-out test is developed, the effect of different OBM compositions on cement-formation bonding are examined, as well as mud removal using spacer.

Chapter 2

Literature Review

This chapter focuses on a literature review of the key petroleum and natural gas engineering principles surrounding zonal isolation and the impact of OBM residuals on cementing operations. This includes an OBMs versus WBMs comparison, invert emulsion drilling fluids, well cementing, and spacer fluids.

2.1: Oil-Based Muds (OBMs) versus Water-Based Muds (WBMs)

The major concern of using OBMs over WBMs in well drilling is its effect on cementing operations. Because of the use of some strong oil-wetting surfactants, OBMs could convert formation rocks to an oil-wet state, reducing the relative permeability to oil (Yan *et al*, 1993). This then would weaken the bonding strength at the formation-cement and casing-cement interfaces and affect the cementing quality (Wang *et al*, 2018). After drilling and casing placement, OBMs used in drilling has to be removed before starting cementing. This can be done by deploying a cleaning fluid, called spacer, to displace the drilling mud and clean up the wellbore before cementing (Pernites *et al*, 2015). However, removing OBMs can be difficult because of its strong adhesion to the casing and the well, that it forms an oily filter-cake on the casing and well and limiting the displacement efficiency. Li *et al*. (2016) has shown that mixing OBMs with cement slurries can negatively affect cementing quality be causing contamination and reducing the compressive strength and thickening time. In addition, Nowak and Krueger (1951) and Krueger and Vogel (1954) have shown that the immediate contact of drilling muds with reservoir rocks can affect both the rock wettability and rock permeability, leading to a reduction of the well's productivity. Moreover, a major drawback to using OBMs over WBMs is that OBMs usually contain more solids, so particle invasion may be more pronounced (Yan *et al*, 1989).

2.2: Invert Emulsion Drilling Fluids

Invert emulsion drilling fluids are fluids that its' emulsion can be converted from a W/O emulsion to an O/W emulsion and vice versa using an acid-base chemical switch. An example for W/O emulsion is oil-based muds (Patel, 1999). These drilling fluids are relatively inexpensive and provide drilling performance similar to OBMs. Moreover, emulsions are formed when a surfactant lowers the surface interfacial tension of one liquid and allow it to make stable droplets inside another liquid. Additionally, the lower the interfacial tension is, the smaller the droplets are and more stable the emulsion becomes (Patel, 1999).

2.3: Well Cementing

Cement is used to hold casing in place and prevent fluid migration between subsurface formations. Cementing operation is done by mixing cement with additives and water, then pumping it through casing and to critical points in the annulus around the casing or in the open hole below the casing string. In addition, cementing operations has two categories, primary cementing and remedial cementing. Primary cementing is done to provide zonal isolation, whereas remedial cementing is done to correct problems associated with the primary cementing. Furthermore, cementing has two main functions, restricting fluid movement between the formations, and supporting the casing. Cementing can also help in many ways, protecting casing from corrosion, preventing blowouts by quickly sealing, protecting the casing from shock loads in drilling deeper depths, and sealing off lost circulation zones. Moreover, cement is designed according to well's parameters such as the depth and that determines the amount of cement used and the variations of pressure and temperature, the wellbore geometry determining the volume of cement needed, the temperature deciding for cement's rheological properties, formation pressures and characteristics.

2.4: Cement-Based Magneto-Rheological Fluid

Cement-based magneto-rheological (MR) fluid is a cement slurry that has magnetic particles in it. An external magnetic field is applied to the fluid allowing the user to control the flow properties and direction by varying the intensity and direction of the magnetic field. The cement-based MR fluid can help displace the drilling fluid efficiently, since cement must maintain an ideal viscosity contrast with spacer and drilling fluids during cementing (Nair et al. 2015).

2.5: Spacer Fluids

2.5.1: Spacer Fluids Applications

Prior to cementing operations, Spacer fluids are typically used to pre-flush the wellbore annulus and displace the drilling fluid and prepare for cementing. Cement slurries and drilling fluids are usually fluids those are chemically incompatible, so that drilling fluids could contaminate cement slurries and cause various problems that will be discussed later. Therefore, the drilling fluid has to be displaced from the annulus before the placement of cement slurry. This operation is generally done by pumping a spacer fluid between the drilling fluid and cement slurries to form a buffer and prevent the drilling fluid and the cement slurry from coming into contact. Since the spacer fluid is coming into contact with and being pumped between the cement slurry and the drilling fluid in the wellbore annulus, the spacer fluid has to be chemically compatible with them (Wilson *et al*, 1989).

2.5.2: Spacer-Drilling Fluids Compatibility

Spacer fluids has to be chemically compatible with the used drilling fluid. The compatibility of the drilling mud with the spacer fluids highly depends on the surfactants used to build the spacer. If contained the appropriate surfactants, the water-based spacer can displace drilling muds and enhance the cement bonding by water-wetting the annular surfaces (JPT staff, 1999). In order for the spacer to function properly, it must contain appropriate types and concentrations of surfactants to achieve a good emulsion switch, and avoid phase separation, solids settling, or viscosity spikes (Heathman et al. 2000). When it contains the appropriate surfactants, the emulsions break properly, avoiding the earlier mentioned problems and allowing a good fluid inversion where the water-in-oil emulsion turns into an oil-in-water emulsion (Heathman et al. 1999).

2.5.3: Alternatives

Although the use of a spacer fluid and drilling fluid displacement is essential prior to cementing operations, an invention has been made by Nahm and Wyant to dispense its use. Their invention was to slightly modify an OBM to have a double nature in job, to be used as a drilling fluid, and then to be left in the annulus to solidify and act a cement slurry. They decided to adjust a preexisting OBM because it is much easier, and less expensive and time consuming than building a new one from scratch. The oil-mud-cement slurry they designed can lower the drilling fluid disposal expenses and save time. Their design provides an OBM composition containing sufficient water and hydraulic material to form a slurry having around 1.4 to 2.2 solids/oil volume ratio and about 0.15 to 0.60 water/hydraulic material weight ratio, in addition to enough accelerator or retarder for the oil-mud-cement to harden (Nahm and Wyant, 1991).

2.5.4: Effect of Casing Centralization on Mud Removal

In addition to the importance of drilling fluid and spacer compatibility for an effective mud displacement, the centralization of the casing in the wellbore plays an important role. Furthermore, if the casing was not centralized in the wellbore, fluids will flow faster and easier within the wider annular gap, where fluids holdups might occur in the narrower gap, leaving behind some mud that could affect cementing, leading to unreliable zonal isolation that might compromise the life of the well (Nair et al. 2015).

Chapter 3

Methodology

This chapter discusses the approaches used in this study to investigate the impact of wettability alteration caused by mud residuals on cement bonding with three different formations, sandstone, limestone, and shale. Three different OBM compositions are used in multiple OWRs: 90/10, 75/25, and 60/40. API class-G cement is prepared and cured under high pressure and high temperature to simulate borehole conditions. In addition, spacer fluid was prepared and used to test the effect of mud removal on cement-formation bonding. Finally, modified push-out tests are performed to tests specimens for shear-bond strengths measurements.

3.1: Specimen Preparation

The specimen comprises a concentric configuration of a rock-core samples inside a casing-grade steel pipe with the area in between the rock and the pipe being filled with a class G cement slurry prepared according to API standards (Fig. 2). In addition, the specimen is cured in a curing chamber under high pressure and high temperature condition of 200 F and 3000 psi using a cement curing chamber (Fig. 3) for 24 hours to mimic borehole conditions. Moreover, the rock cores were drilling using a core drilling machine (Fig. 4) and cut using a rock cutting machine (Fig. 5). The rock cylindrical sample dimensions are 1 in. in diameter by 2 in. in height, and the pipe is 3.5 in. in OD, 2.6 in. in ID and 2 in. in height (Fig. 6). Three different rocks were evaluated, sandstone, limestone and shale.

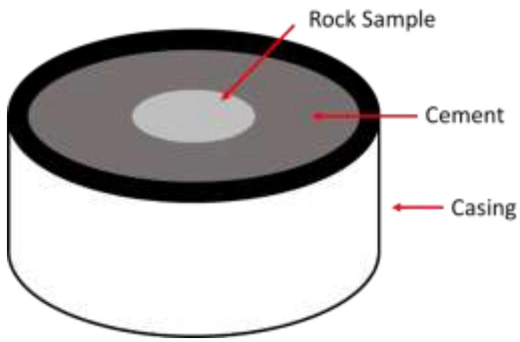

Figure 2. Schematic of a push-out sample

Figure 3. High pressure and high temperature cement curing chamber

Figure 4. Rock core drilling machine

Figure 5. Rock cutting machine

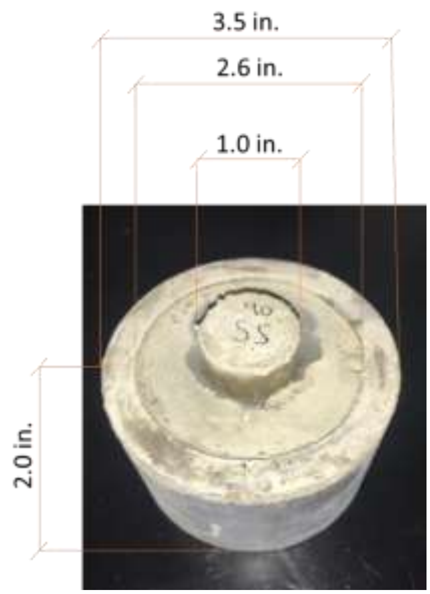

Figure 6. Specimen dimensions

In the experiments, three distinct scenarios were evaluated. The first scenario is rock cores saturated in water at room pressure and temperature for 24 hours to allow air bubbles to escape rock pores. The second scenario is rock cores saturated in water, then preconditioned in OBM for 24 hours at 140 ºF and 600 psi inside a HPHT filter press (Fig. 7). In the third scenario, after being preconditioned in OBM, the rocks were washed with spacer fluid for 10 minutes using a magnetic stirrer at room pressure and temperature to displace OBM residuals and water-wet the outside surface.

Figure 7. High pressure and high temperature filter press used to saturate rock-cores with OBM

3.2: Push-out Test

The prepared specimen was then tested under 0.3 mm/min rate of axial platen (Fig. 8) for shear-bond strength measurements and stopped at a 12 mm displacement. The displacement was enough to return a peak load value. Figure 9 represents a load vs. displacement curve for a shale sample saturated in water. It can be seen that the load builds up quickly until it reaches failure then drops gradually as the displacement proceeds and continues at a residual value due to friction of the core to the cement.

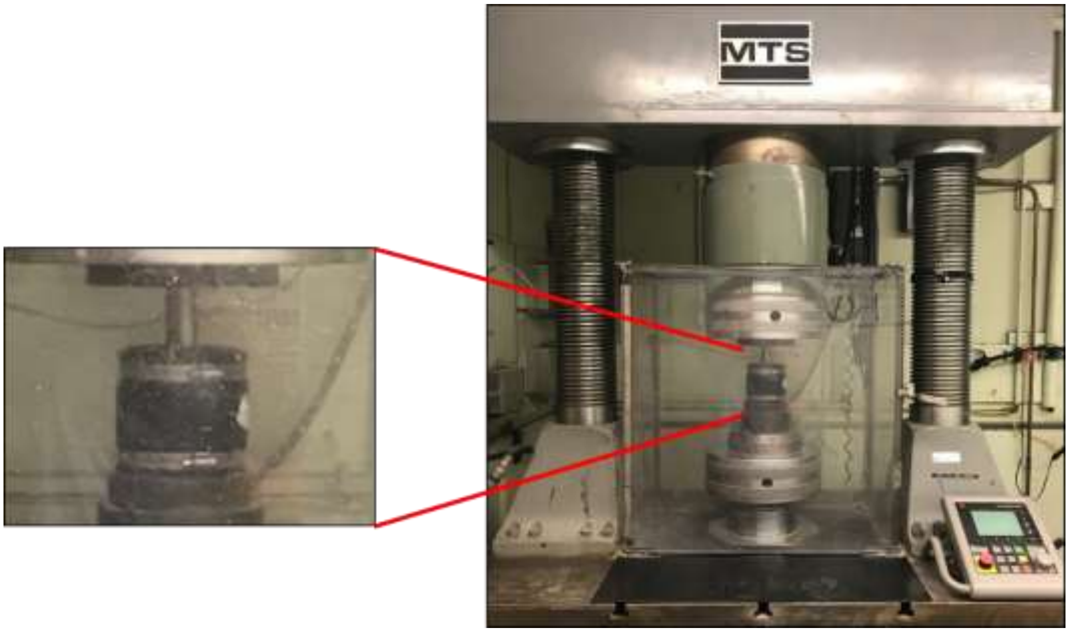

Figure 8. A specimen being tested under axial load frame

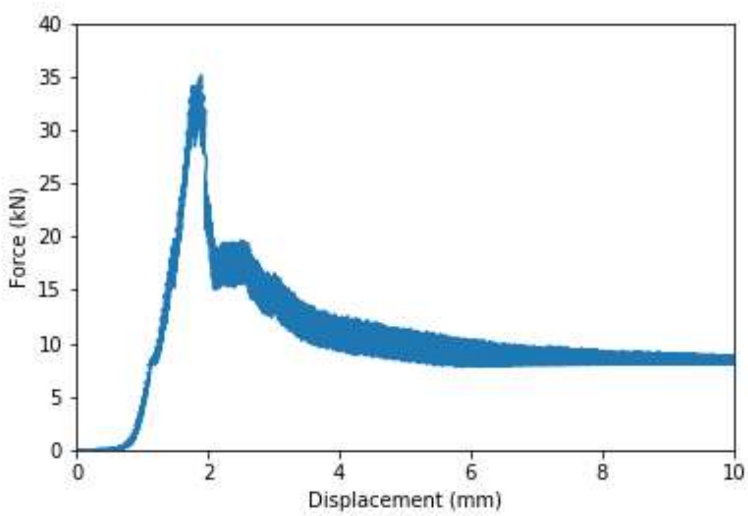

Figure 9. Load vs. Displacement curve for a shale sample saturated in water

The shear bond strength is calculated by taking the peak load value and dividing it by the contact cross-sectional area (Fig.10):

$$\sigma = \frac{Force}{Cross - Sectional\ Area} = \frac{F_{max}}{\pi d h}$$

Where σ is the shear bond strength, F_{max} is the peak load value, d is the rock-core diameter, and h is the rock-core height.

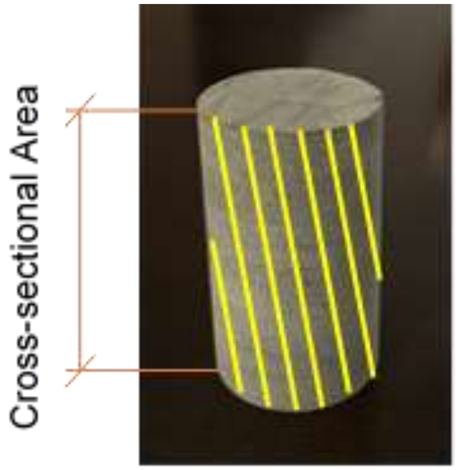

Figure 10. A representation of the rock-cement contact area (the whole circumference area is yellow-dashed)

3.3: OBMs Preparation

Three different oil-based muds were prepared in multiple OWRs: 60/40, 75/25, and 90/10, and the components are listed in Table 1.

Table 1. Oil-based muds components

OWR	60/40	75/25	90/10
Diesel (ml)	364.25	448.96	531.34
Water (ml)	239.68	147.71	58.27
Barite (gr)	224.23	260.10	294.97
$CaCl_2$ (gr)	12.63	7.78	3.07
Bentonite (gr)	30	30	30
Emulsifiers (gr)	28.5	28.5	28.5

The rheology of the drilling fluids was measured in a rotational rheometer and the values obtained are listed in Table 2.

Table 2. Rheology of oil-based muds

OWR	60/40	75/25	90/10
Speed (RPM)	Dial Reading (lbm/100 ft^2)		
600	133	68	26
300	94	46	21.5
200	79	37	13
100	60	27.5	9
6	29	12	4
3	27	11	3.5

3.4: Cement Preparation

Class G cement was prepared according to API standards with 44/56 water/cement mass ratio and poured in the annular space between the rock and steel pipe. The specimen was cured in a curing chamber under 200 ºF and 3000 psi for 24 hours.

3.5: Spacer Preparation

Spacer fluid was prepared according to manufacturer’s standard specifications with 97.06% mass of deionized water to total mass of spacer and water.

3.6: Spacer-OBM Compatibility Test

A spacer-OBM compatibility test was done using the rheometer to evaluate the performance of the spacer and decide if the addition of a polymer was essential (Fig.11). The compatibility test is done by running the rheometer at 100 rpm in a cup filled of OBM for 2 minutes, then in a spacer cup for 2 minutes, and then in a water cup. An initial mud displacement test showed negative spacer compatibility and an amount of spacer polymer equivalent to 5.04% of spacer fluid mass needed to be added to reach the desired mud displacement.

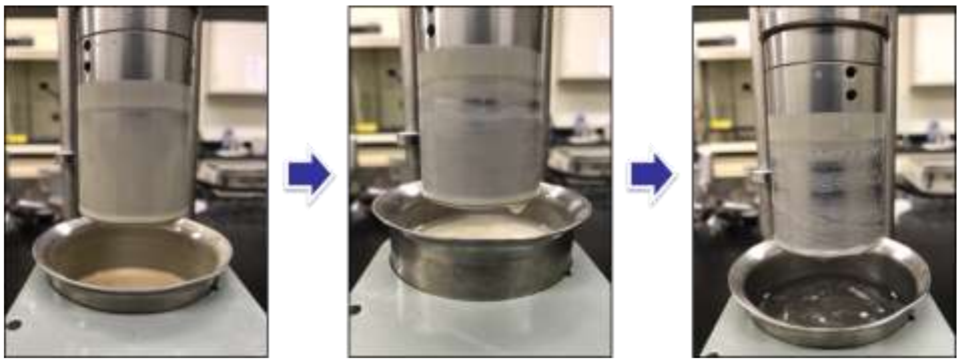

Figure 11. Spacer-OBM compatibility test steps using a rheometer

Chapter 4

Results and Discussions

4.1: Water-Saturated Samples

Push-out tests were run for the rock-core samples saturated in water and the results are shown in Fig. 12. It has been observed that the shear-bond strength values for limestone and sandstone samples were very similar but they were substantially lower than shale. As mentioned by Zhang *et al.*, (2017), the reasoning behind that observation is that shales tend to swell when saturated with water due to the hydration of clays. The measured shear-bond strengths for water-saturated samples are used as reference values to be compared with the following oil-saturated samples.

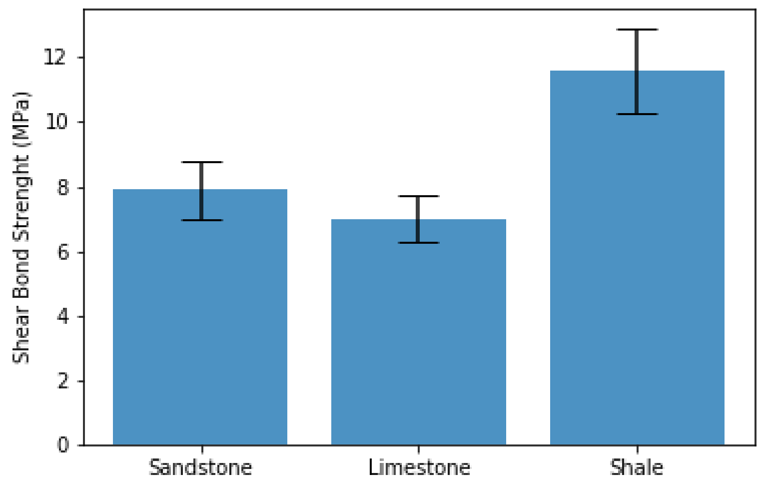

Figure 12. Shear-bond strength values for different water-saturated rocks

4.2: Oil-Saturated Samples

The Effect of OBM's OWR in the shear bond is observed in Fig. 13. Overall, shear bond strengths had an 85% decrease compared to water-saturated values. It is notable that the lower the OWR, the smaller the bond between cement and formation. However, the difference between them is not significant. This difference could be due to the formation of mud cake that is more pronounced in samples soaked in a lower OWR OBM. Figure 14 shows two rock-cores with different mud-cake thicknesses. The difference between the three lithologies is also very small. Due to the inhibit nature of OBMs, no apparent swelling occurred in the clays, thus, shale values are not higher than the other samples.

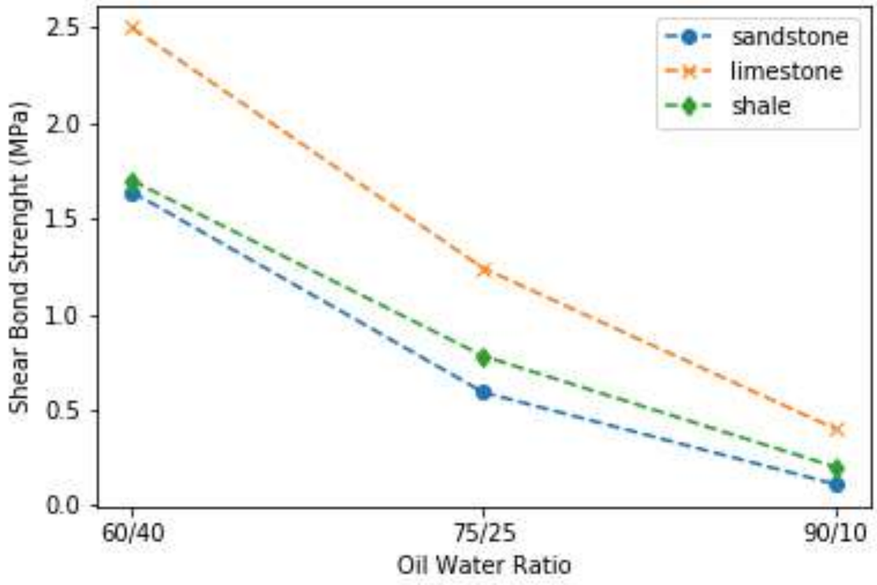

Figure 13. Shear-bond strength values for different oil-saturated rocks

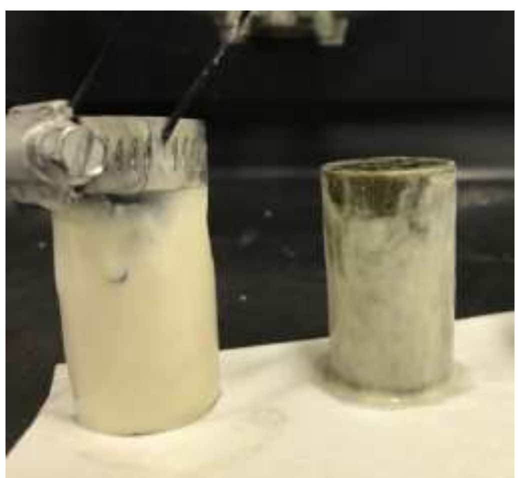

Figure 14. Two rock-cores with different mud-cake thicknesses

4.3: Spacer-Flushed Samples

For the samples washed with spacer fluid, their bond strengths increased, but did not return to the original values (Fig. 15). The spacer might not have removed all OBM, due to rocks long exposure to the OBM under high pressures where muds could have accumulated inside the pores. Figure 16 represents an oil-saturated shale core flushed with spacer where some OBM residuals are left behind. The results demonstrate that the shear bond doubled in relation to when no spacer was used. The mud residuals are responsible for the decrease in bond strength, when compared to water.

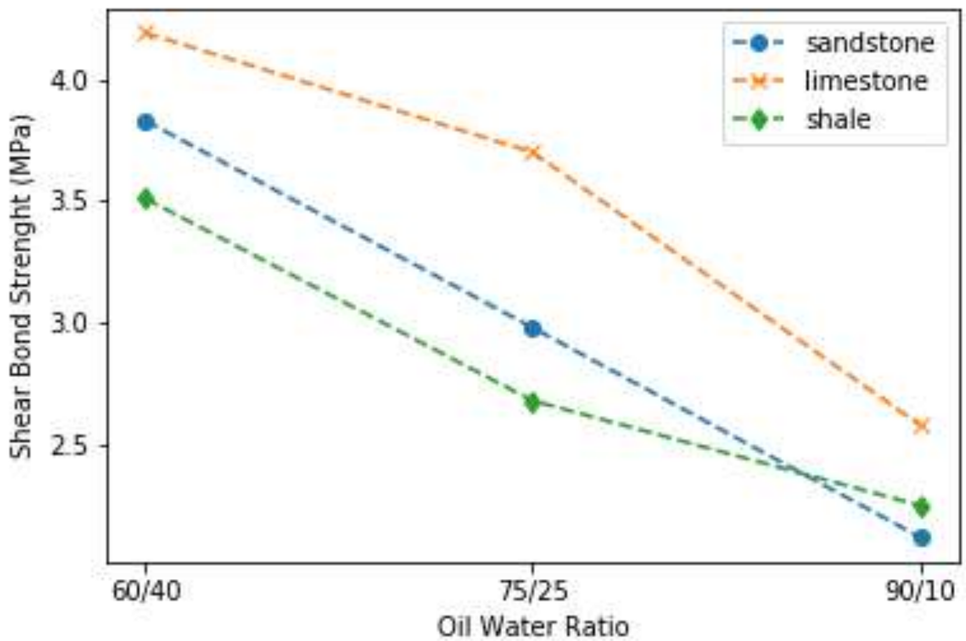

Figure 15. Shear-bond strength values for different oil-saturated rocks flushed with spacer

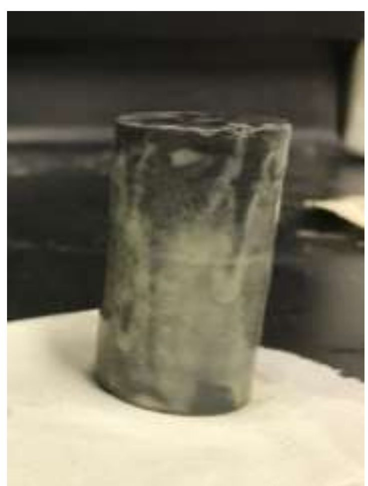

Figure 16. An oil-saturated shale core flushed with spacer

Finally, figures 17, 18 and 19 includes summarized shear bond strength bar graphs for different scenarios done on different rock formations: sandstone, limestone, and shales.

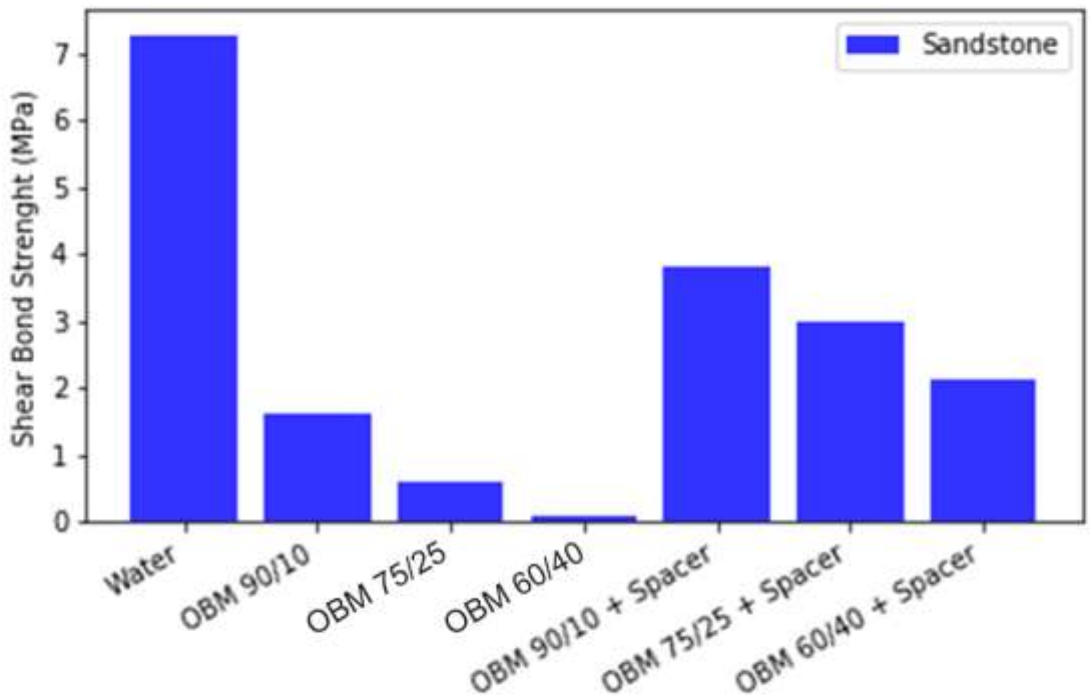

Figure 17. Comparison of shear-bond strengths for different fluid systems in sandstone

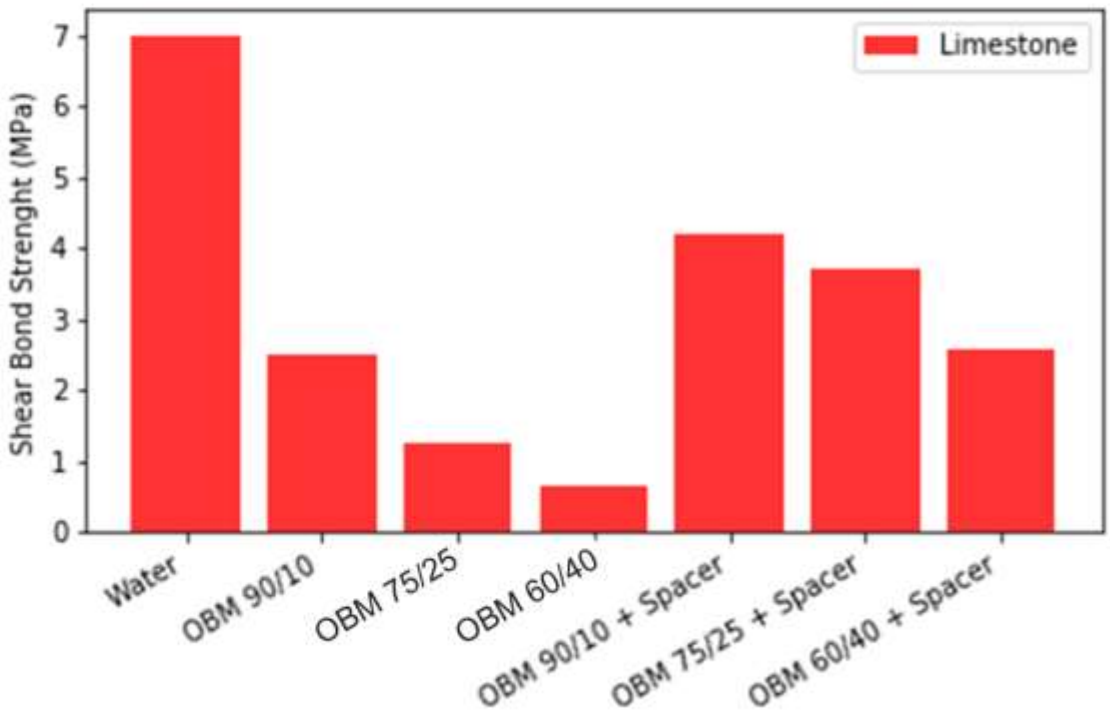

Figure 18. Comparison of shear-bond strengths for different fluid systems in limestone

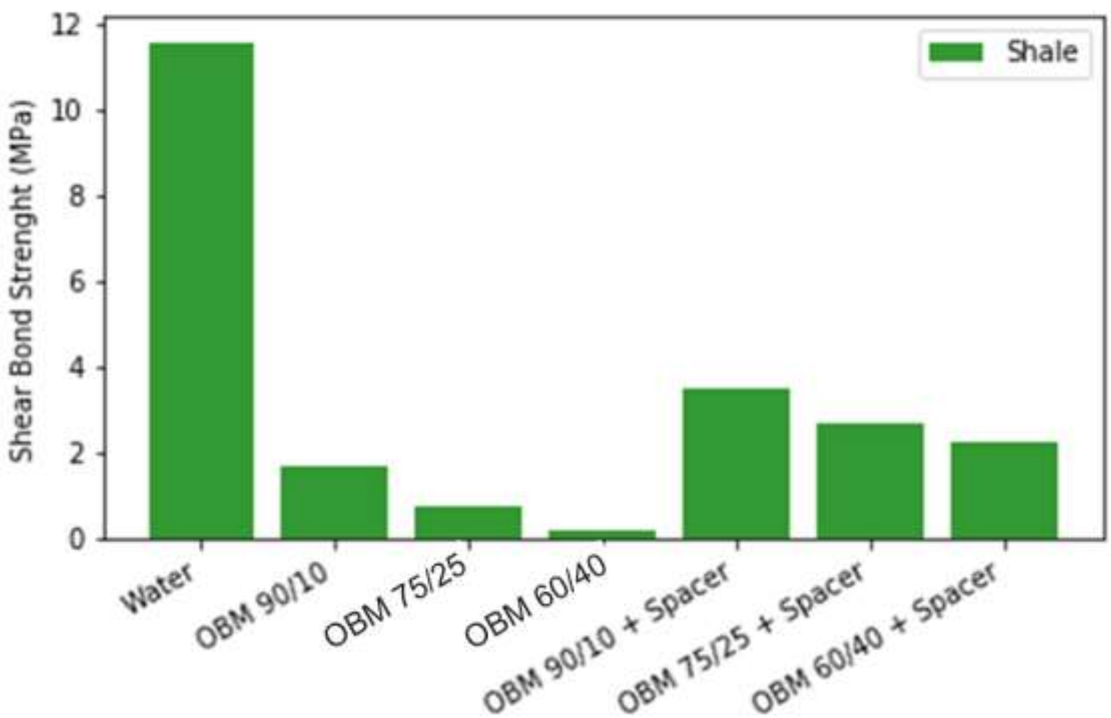

Figure 19 . Comparison of shear-bond strengths for different fluid systems in shale

4.4: Mud-Cake Thickness

Mud-cake thickness has a great impact on cement-formation bonding. Rock-cores with thicker mud-cakes returned lower shear-bond strengths than cores with thinner mud-cakes. In addition, it can be observed from Figures 20, 21, and 22 that rocks contacted with lower OWR OBMs contain thicker mud-cake in the interface between rock-cores and cement.

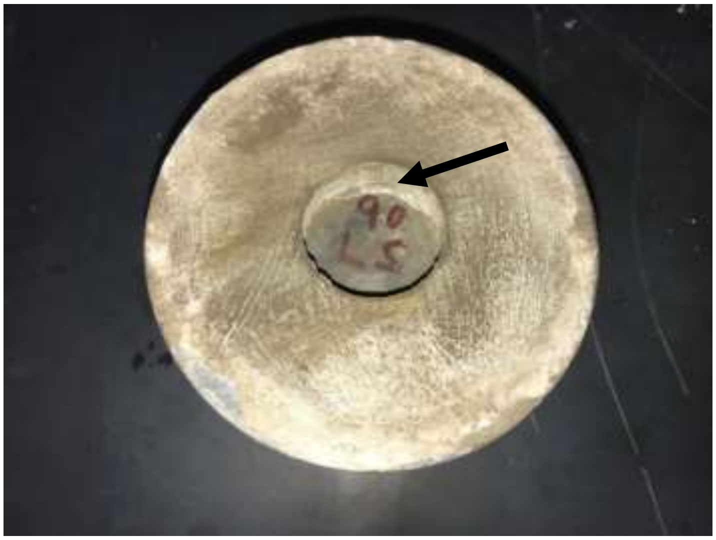

Figure 20. 90/10 OBM-saturated specimen. The arrow shows the mud-cake at the cement-formation interface

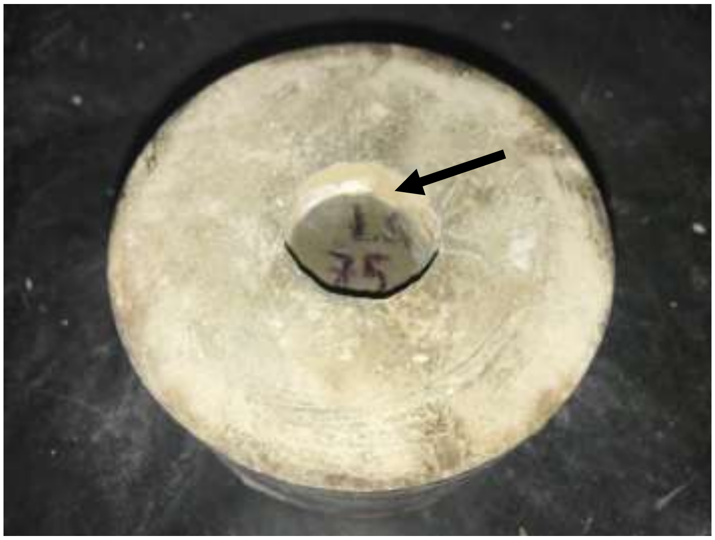

Figure 21. 75/25 OBM-saturated specimen. The arrow shows the mud-cake at the cement-formation interface

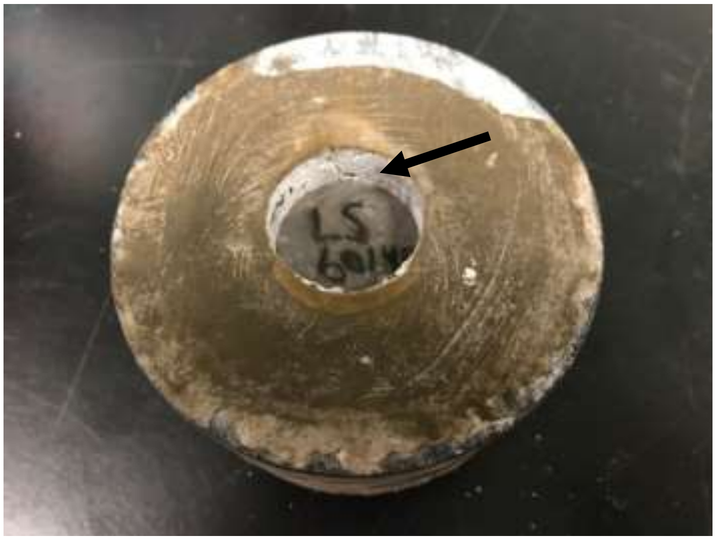

Figure 22. 60/40 OBM-saturated specimen. The arrow shows the mud-cake at the cement-formation interface

Chapter 5

Conclusions and Recommendations

The results suggest that the use of spacer improved the bonding but not to the initial condition. The spacer did not completely remove the OBM and a filter cake might have been left at the interfaces. At the absence of mud-cake the shear bond values are still around two times higher than the ones obtained with spacer. This is not valid for shale, which presented values unusually high in the absence of mud-cake, as explained earlier in this work. The following conclusions can be drawn from this study:

1) The designed push-out test is an effective tool to study the effect of mud removal on shear bond strength.
2) Shale expansion due to clay swelling is responsible for higher shear bond strength when the rock-core is saturated in water. Such phenomenon is not observed in OBM due to its inhibiting nature to clay.
3) No significant difference in shear bond strength is observed in the results of the experiments with the different lithologies: sandstone, limestone, and shale.
4) Lower OWR has a larger impact on bond strength due to thicker mud cake forming around the rock-core, but the difference between the different OWR bond strength values is not substantial.
5) The exposure to spacer fluid was not enough to remove all OBM residuals as verified by the lower shear bond strength in comparison with rock samples saturated in water that had no mud-cake.

Using drilling muds is essential in drilling operations, OBM specifically is used in most shale formations. The data shows that using OBM returned lower cement-formation shear bond strength values even after displacing it with spacer. It also shows that lower OWR OBMs tend to form thicker mud cakes that weaken cement bonds more; thus, it can be concluded that higher OWR OBMs are best used in drilling operations where drilling with OBMs is recommended. In addition, using spacer to displace OBM residuals returned substantially higher cement bond strengths compared to when spacer was not used; thus, it can be concluded that using a well formulated spacer fluid is important to have the best cementing operation.

Further research that could be done includes extending the study to account for the cement-casing interface, testing different WBMs and comparing its results with OBMs to decide what drilling mud is optimal for cementing in different formations. Future works should include different spacer formulation, better flushing system with stronger stirrer, and longer exposure time to dynamic bath as an attempt to improve the mud removal.

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ACADEMIC VITA

Anwar S. Alghamdi

anwar.alghamdi.7@hotmail.com • +966-550955590

PO BOX 5103
Ras Tanura, Eastern Provence, 31311, Saudi Arabia

EDUCATION

Pennsylvania State University, University Park, PA 2019

- Schreyer Honors Scholar
  - Honors Thesis: Experimental Evaluation of the Impact of Oil-Based Mud Residuals on Cement-Formation Bonding Strength
- Bachelor of Science in Petroleum and Natural Gas Engineering
- Bachelor of Science in Economics

HONORS / AWARDS

Prince Mohammed Bin Fahad Award for Academic Excellence	2007
1st Place Saudi Arabia Eastern Province Mathematics Olympics	2007
Penn State Dean's list: 4 semesters	Fall 2015, Spring 2016, Fall 2016, Fall 2017
Saudi Aramco Company Undergraduate Degree Scholarship	2014-2019
2nd Place 2019 Eastern North America Regional Student Paper Contest	2019

TEACHING EXPERIENCE

Chemistry 110 Lecture Assistant at Penn State — Fall 2016, Spring 2017

- Answering students' questions in classroom
- Holding 2 weekly recitations with a TA
- Holding exam review sessions prior to each exam

LEADERSHIP EXPERIENCE

Vice President of the Saudi Arabian Student Association at Penn State — Summer 2017-Spring 2018

PROFESSIONAL TRAINING & CERTIFICATES

One-month Summer Academic Program at Saudi Aramco	June – July 2012
H2S Awareness Training at Rawabi United Safety Services CO. LTD.	December 2014

VOLUNTEER EXPERIENCE

Ras Tanura Area Ramadan Iftar Campaign	August – September 2010
Ras Tanura Area Environmental Campaign	December 2013
Saudi Aramco Mangrove Planting Campaign	April 2013
Saudi Aramco GCC Traffic Week	March 2013
Ras Tanura Area National Day Celebration	September 2014
TEDxPSU	February 2016
Ramadan Iftar Campaign at Penn State	June 2017
New Saudi Students Orientation at Penn State	August 2017
Eid Aladha Celebration at Penn State	September 2017
THON Trip Donation Collection at Penn State	September 2017
Saudi National Day Celebration at Penn State	September 2017
SASA Café Intellectual Discussions at Penn State	Weekly: October 2017-December 2017
Arab Tent II at Penn State	April 2018

SKILLS

Fluent in both Arabic and English
Advanced user of Microsoft Windows, Microsoft Office
Intermediate programming skills in C++ and MATLAB
Effective communication skills
Able to adapt oneself to new surroundings