Preventing and Remedying Loss of Circulation Using MR (Magnetorheological) Fluids

by

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Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Chemical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

(Ir Abdul Aziz)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
May 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(Allamurad Durdiyev)

ABSTRACT

The problem of lost circulation became apparent in the early history of the drilling industry and was magnified considerably when operators began drilling deeper wells and/or through depleted formations. The industry spends millions of dollars a year to combat lost circulation and the detrimental effects it propagates, such as lost of rig time, stuck pipe, side-tracks, blow-outs and, occasionally, the abandonment of expensive wells. The main objective of this project is to determine whether Magnetorheological fluids are capable of preventing or remedying the loss of circulation. Experiments using HTHP (high temperature, high pressure) Filter Test were conducted in order to conclude the performance of MR fluids in loss circulation prevention and remedying.

ACKNOWLEDGEMENT

"He has a right to criticize, who has a heart to help"

Abraham Lincoln

I am sending my deepest appreciation to all those who have contributed in any way for the successful ending of my Final Year Project:

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- Dedicated to my beloved father. Rest in peace!

Allamurad Durdiyev

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

1.1.1 Lost Circulation

Lost circulation is best defined as the uncontrolled flow of whole mud into a formation. This can occur in naturally cavernous, fissured, or coarsely permeable beds, or can be artificially induced by hydraulically or mechanically fracturing the rock, thereby giving the fluid a channel in which to travel.

- Induced Losses

- Naturally Occurring Losses

An excessive overbalanced condition, where the formation is unable to withstand the effective load imposed upon it by the drilling fluid can cause lost circulation. Excessive drilling fluid density is the most common cause of this condition. Excessive drilling fluid density can be the result of inadequate or inaccurate well planning (pore pressure and fracture gradient prediction), poor or nonexistent solids control, or can be the result of poor rheology or circulating system hydraulics. Any mechanical condition which causes an abnormal pressure surge can cause wellbore instability, and may cause lost circulation. Examples of these conditions may be: pump surges, bit and stabilizer balling, poor wellbore cleaning, abnormally high pump flow rates, poorly designed wellbore geometry, and poor fluid properties, making it difficult to break circulation after the fluid has been static. Lost circulation can be an expensive and time-consuming problem. During drilling, this loss may vary from a gradual lowering of the mud in the pits to a complete loss of returns.

The major consequences of lost circulation include the following:

-The possibility of a blowout because of a drop in the mud level.

-The possibility of sticking the drill pipe because of poor cuttings removal.

-No zonal isolation due to insufficient cement fill-up.

-Excessive cost because of loss of mud, increased rig time, and remedial cementing operations.

-Losses to the producing zone resulting in extensive formation damage.

-The loss of the well

Seeping losses can occur with any type of lost circulation zone, when the solids in the mud are not sufficiently fine to seal the formation face. Partial losses frequently occur in highly permeable gravels, small natural fractures, or as a result of fracture initiation. Complete losses are usually confined to long gravel sections, large natural fractures, wide induced fractures, or cavernous formations.

Induced losses:

- Usually occurs when formation can`t withstand the effective load imposed by drilling fluid.
- Excessive drilling fluid density is the most common cause of this condition.
- Mechanical condition which causes abnormal activity can cause lost circulation.
- Examples: pump surges, bit and stabilizer balling, poor hole cleaning, abnormally high pump flow rates, poorly designed hole geometry, and poor fluid properties.

Naturally occurring losses

- Circulation in a drilling well can be lost into open fractures which are pre-existing.

- When circulation is lost the first step should be diagnosis, where and why the loss is occurring.

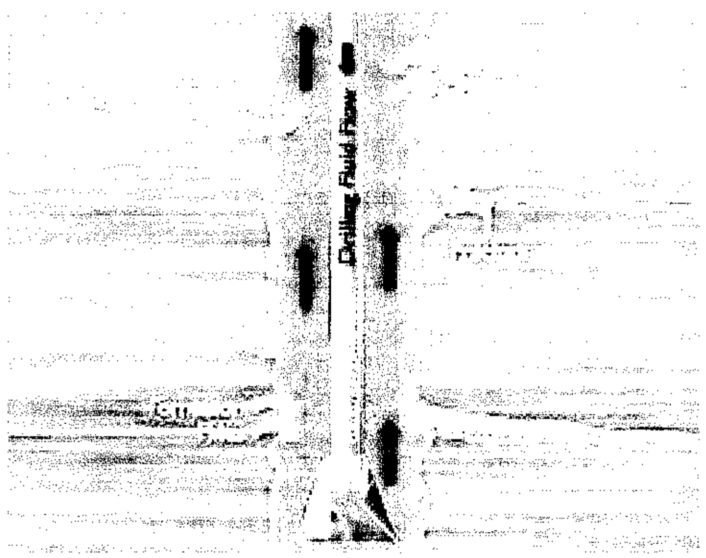


Figure 1: Lost circulation overview

1.1.2 MR Fluids

Magnetorheological fluid specially enhanced fluid, which is basically iron particles containing in Olefin, is very helpful in reaching the desired gel form and more viscous form in most rapid rates. When there is a magnetic field applied to this substance, the rapid change from liquid form to viscous gel form can be witnessed. This ability of MR fluid makes it very special and gives new vision in solving problems such as: loss of circulation and cutting transport. The change into more viscous condition of the fluid is explained by iron particles that start to activate, when magnetic field surrounds the fluid.

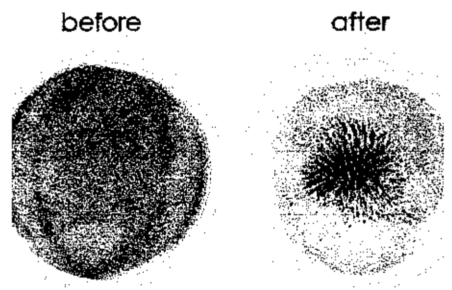


Figure 2: Magnetorheological fluid before and after exposure to a magnetic field

1.1.3 Filter Cake

Filter cake is the remains deposited on a permeable medium when a slurry, such as a drilling fluid, is forced against the medium under a pressure. Filtrate, in this case the drilling fluid, passes through the medium, leaving the cake on the medium. Drilling fluids are tested to determine filtration rate and filter-cake properties. Cake properties such as cake thickness, toughness, slickness and permeability are important because the cake that forms on permeable zones in the wellbore can cause stuck pipe and other problems. In loss circulation filter cake plays important role of preventing the fluid to flow into formation. The filter cake thickness is determined by HTHP filter tests and these experiments are essential parts of daily routine on drilling site. The size of the deformed area of filter cake and its curvature will depend on the extent of pressure fluctuation beneath the cake. The radius of curvature *R* can be defined with the aid of two lengths, *a* – the half-width of the deformed zone and *b* – its height above the rock surface:

$$R = \frac{a^2 + b^2}{2b}$$

1.2 PROBLEM STATEMENT

Despite of various techniques towards healing the lost circulation, there are many downsides of these ways which lead to other problems. The increase of gel strength for healing the lost circulation may lead to stuck pipe problems and on the other hand thickening the filter cake may cause the same problems plus low permeability. All these problems lead to the fact that we need much more efficient way of solving lost circulation problems. There are steps that should be followed in any case of lost circulation. These problems should be attacked first in order to deal with this problem.

This project will be aimed at performing experiments by using MR fluid in order to research and recommend the best way of using the MR fluid in lost circulation condition.

1.3 OBJECTIVES AND SCOPE OF STUDY

The objectives of this project include in itself the feasible tests, which are going to lead to the best variant. By, changing the concentration and magnetic field reading we will observe how MR fluids in combination with magnetic field effect the drilling fluid and conclude whether it is efficient or not.

The objectives of this project are

- ❖ To enable magnetic field usage in laboratory conditions.
- ❖ To investigate the behavior of filter cake after injecting MR fluid in it and applying magnetic field.
- ❖ To perform HTHP filter test trials for analyzing the efficiency and downsides of MR fluid in loss circulation.

CHAPTER 2

LITERATURE REVIEW

2.1 Conventional Ways of Treating the Loss of Circulation

As by a tradition there are several ways of attacking the lost circulation proble to remedy the effects. This part of the paper will take a look at commnly used tecniques to heal the lost circulation.

When induced loss of circulation occurs, addition of loss circulation materials is not usually very effective. This is particularly true if the mud density is high, 14 lb/gal or greater. Fine loss circulation material which does not adsorb a lot of water should be used in weighted mud. Recommended procedures are:

Shut down the pump.

- Monitor fluid level in the annulus (the reduction in pressure due to cessation of fluid flow may be sufficient to stabilize a minor loss.)
- If the fluid level is down, fill the hole with water or diesel (base fluid), and monitor the number of barrels required.
- If the loss is severe, the bit should be pulled up into the casing to prevent stuck pipe.
- In the case of minor losses, where the hole appears to be stable after shutting the pump down, an attempt to regain complete circulation
- If it is necessary to fill the hole with water or diesel, an estimation of the loss point (generally assumed to be the casing shoe), and the volume of water used will allow a calculation of the effective fluid density which the wellbore can support. This is an important calculation since it helps determine what corrective measures may be applied.

There are several stages of remedial of lost circulation and this figure below shows all the steps that should be taken and are taken as traditional techniques in Central Asia. It shows detailed steps of solving the problem. Every step here should be made according to the fracture diameter and other aspects that effect the decision.

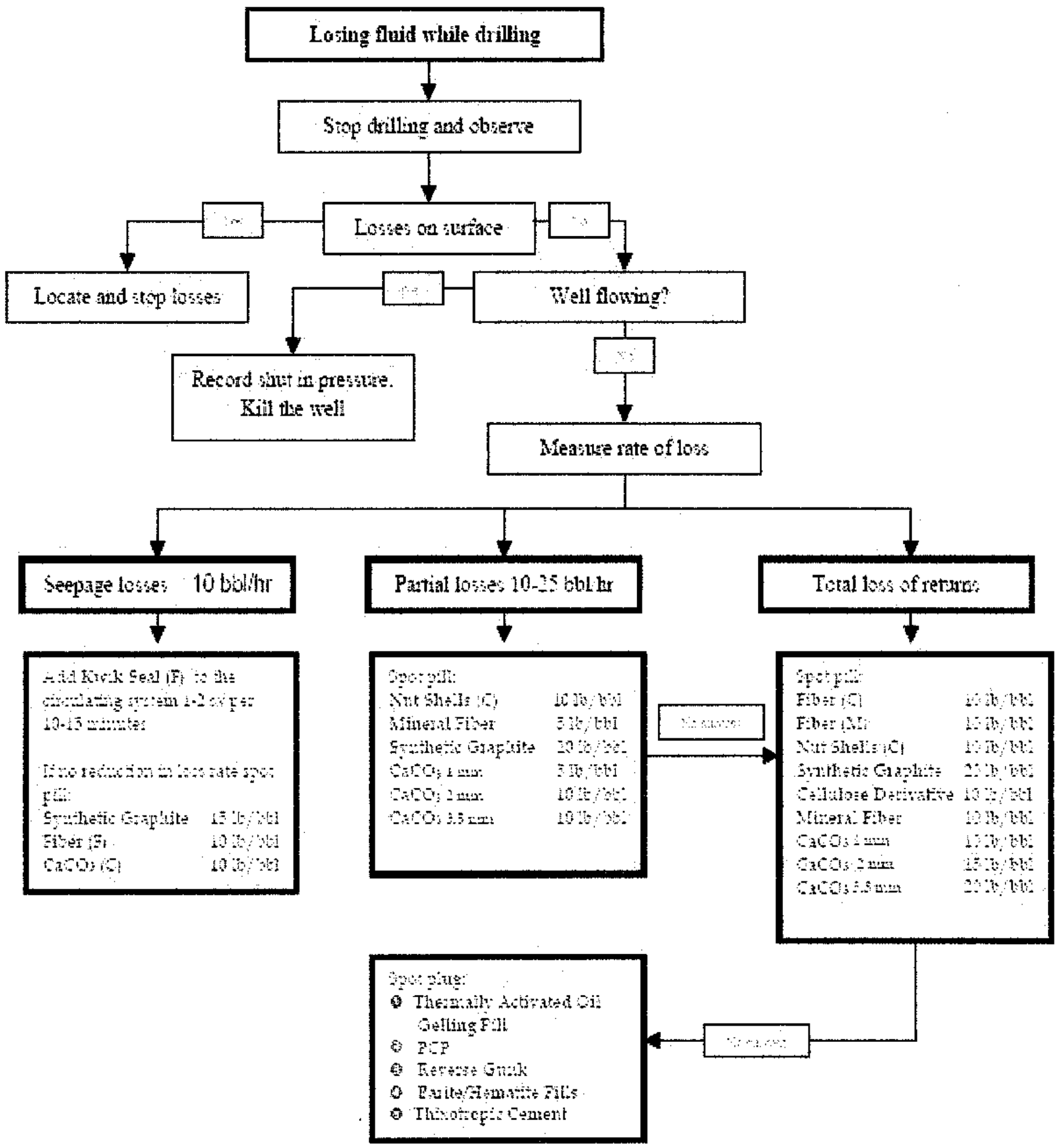


Figure 3: The Lost Circulation Assessment and Planning decision tree covering conventional, specialized and contingency lost circulation treatments for a naturally fractured carbonate well in Central Asia.

2.2 Remedying lost circulation (sealing agents)

There are a great variety of materials available to use as sealing agents for loss of circulation. The following chart gives an indication of the size of fractures scaled by different materials. Sealing is one of the most commonly used techniques in remedial of lost circulation problem. Figure below shows some of the sealing agents according to their properties.

As it can be observed from the figure, sealing agents are restricted in their performance towards loss circulation remedying, by the size of the fracture.

Material	Type	Description	Concentration (lb/bbl)
Nutshell	Granular	50% - 3/16+ 10 mesh 50% - 10+ 100 mesh	20
Plastic	Granular	50% - 3/16+ 10 mesh 50% - 10+ 100 mesh	20
Limestone	Granular	50% - 3/16+ 10 mesh 50% - 10+ 100 mesh	40
Sulphur	Granular	50% - 3/16+ 10 mesh 50% - 10+ 100 mesh	120
Nutshell	Granular	50% - 10+ 16 mesh 50% - 30+ 100 mesh	20
Expanded Percite	Granular	50% - 3/16+ 10 mesh 50% - 10+ 100 mesh	60
Cellophane	Laminated	3/4-in flakes	6

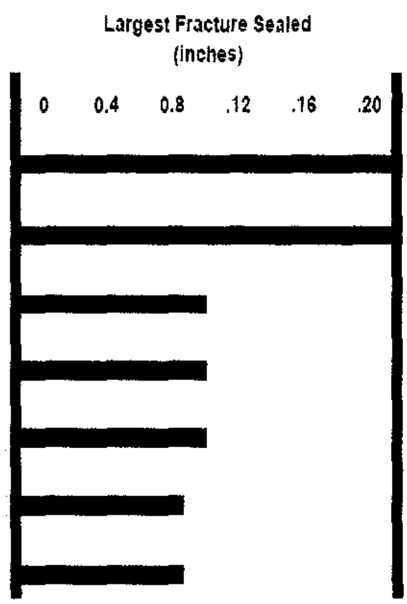


Figure 4: Sealing agents according to their properties (Amoco-Drilling Fluids Manual)

2.3 Remedying loss of circulation (plugging)

When a loss zone cannot be stabilized with sealing materials it may be desirable to try a plug. Several choices and techniques are available; however, in all cases a reasonably accurate estimate of depth of the loss is required prior to setting the plug. Spinner surveys, radioactive traces, and temperature surveys are most commonly used for this purpose. In any lost circulation case, remedial action should center on reducing the effective mud density. This may involve changing fluid or flow properties, or both, to reduce the load applied by the fluid to the formation while pumping. Well control needs must always be taken into consideration prior to reducing the fluid density. A barite plug can be used to remedy induced loss of circulation. In extreme cases the zone can be cemented to remedy loss of circulation. The following are recommendations for composition and application of barite plugs.

Formulation Plug Density (lb/gal)	16	17	18	19
Composition per final Bbl				
Water (Bbl)	.71	.68	.64	.60
Chrome Lignosulfonate (lb)	5.7	5.4	5.1	4.8
Caustic Soda (lb)	1.1	1.0	1.0	0.9
Barite (lb)	422	477	533	588

Figure 5: Standard plug mixing example (Amoco-Drilling Fluids Manual)

CHAPTER 3

METHODOLOGY

3.1 SAMPLE PREPARATION

3.1.1 Drilling fluid preparation

The first step in our methodology is preparing a drilling fluid that is convenient for using. The experiment requires a drilling fluid with specific criteria and there are several recipes, which are used in drilling fluid preparation.

First of all, in this step the problem of selecting the type of drilling fluid was tackled. As there are two types of drilling fluids, water based mud and oil based mud, there is a selection to be made. Water based mud is the type of a mud, where the major liquid is water and all the additives are dissolved in water. It is known as the cheapest among two types of drilling fluids, water based and oil based. For its financial purposes it is widely used in many drilling operations. For our experiment water based mud was used at the beginning, but because of the problems of mixing with MR fluid the experiment was decided to be failed. Due to its composition, which contains olefin and iron particles, the full mixture of MR fluid and total dissolving was not reached.

The second type is an oil based mud, which has oil as its main liquid with small percentage of water. For better solution of MR fluid, this type of drilling fluid was decided to be used. The recipe for the mixing of a drilling fluid was prepared and all the additives with their respective concentrations were added.

Fluid Loss Control (Versatrol) (g)	-	2	10	10
PolyPac UL (Fluid Loss reducer) (g)	3	4	-	-
Confi-MUL S (g) secondary emulsifier	-	-	5	5
Confi-MUL P (g) primary emulsifier	2	4	5	5
Barite (g) weighting agent	220	200	200	240
Brine (ml) + H2O	105	50	53	100
Bentonite(Clay) (g)	4	10	5	10
Lime (g) alkalinity agent	4	4	4	4

Table 1: Recipe for mixing a drilling fluid.

After adding all the additives into the diesel, which was used as the major liquid, the mixing process was held. Using the mixer in the lab, the desired state of a drilling fluid was reached.

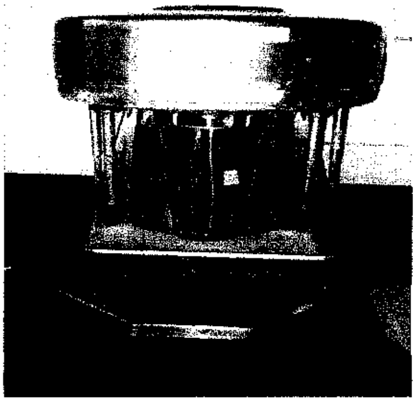


Figure 6: Mixer

Next step was to measure the properties of our drilling fluid, in order to record our data for the following step. Mud balance equipment and Viscometer were used for these purposes. Rheological data was gotten from viscometer readings and the density was measured by mud balance equipment.

Mud density is commonly measured with a mud balance capable of ±0.1 lb/gal accuracy. A mud balance calibrated with fresh water at 70° ±5° should give a reading of 8.3 lb/gal.

1. Measure and record the temperature of the sample of mud to be tested.

2. Place the mud balance base on a flat, level surface.

3. Fill the clean, dry, mud balance cup with the sample of mud to be tested. Rotate cap until it is firmly seated. Ensure that some mud is expelled through the hole in the cap to remove any trapped air or gas.

4. Place thumb over hole in cap and hold the cap firmly on the cup. Wash or wipe the outside of the cup, and dry.

5. Place balance arm on the support base and balance it by moving the rider along the graduated scale until the level bubble is centered under the center line.

6. Read the density (weight) of the mud shown at the left-hand edge of the rider.

A rotational viscometer is used to measure shear rate/shear stress of a drilling fluid - from which the Bingham Plastic parameters, PV and YP, are calculated directly. Other rheological models can be applied using the same data. The instrument is also used to measure thixotropic properties, gel strengths.

Plastic Viscosity (PV) and Yield Point (YP)

1. Obtain a sample of the mud to be tested. Measurements should be made with minimum delay.

2. Fill thermal cup approximately 2/3 full with mud sample. Place thermal cup on viscometer stand. Raise cup and stand until rotary sleeve is immersed to scribe lie on sleeve. Lock into place by turning locking mechanism.

3. Place thermometer in thermal cup containing sample. Heat or cool sample to desired test temperature of 115° ±2°F.

4. Flip VG meter toggle switch, located on right rear side of VG meter, to high position by pulling forward.

5. Position red knob on top of VG meter to the 600-rpm speed. When the red knob is in the bottom position and the toggle switch is in the forward (high) position -this is the 600-rpm speed.

6. With the sleeve rotating at 600-rpm, wait for dial reading in the top front window of VG meter to stabilize (minimum 10 seconds. Record 600-rpm dial reading.)

7. With red knob in bottom position, flip the VG meter toggle switch to low position by pushing the toggle switch away from you. Wait for dial reading to stabilize (minimum 10 seconds). Record 300-rpm dial reading. [See Step 8 to calculate the Plastic Viscosity and Yield Point].

8. The Plastic Viscosity and Yield Point are calculated from the 600-rpm and 300-rpm dial readings as follows:

Gel Strength (10-sec/10-min)

1. With red knob in bottom position, flip toggle switch to 600-rpm position (forward position). Stir mud sample for 10 seconds. Rheological properties measured with a rotational viscometer are commonly used to indicate solids buildup, flocculation or deflocculating of solids, lifting and suspension capabilities, and to calculate hydraulics of a drilling fluid.

2. Position red knob to the 3-rpm speed. When the red knob is in the middle position and the toggle switch is in low (rear) position - this is the 3-rpm speed. Flip toggle switch to off position. Allow mud to stand undisturbed for 10 seconds.

3. After 10 seconds, flip toggle switch to low (rear) position and note the maximum dial reading. This maximum dial deflection is the 10-second (initial) gel strength in lb/100 ft2.

4. Pull toggle switch to high and position red knob to 600-rpm speed. Stir mud for 10 seconds.

5. After 10 seconds, and while mud is still stirring, position red knob to the 3-rpm speed. Flip toggle switch to off position and allow mud to stand undisturbed for 10 minutes.

6. After 10 minutes, flip toggle switch to low (rear) position and note the maximum dial reading. This maximum dial deflection is the 10-minute gel strength in lb/100 ft2.

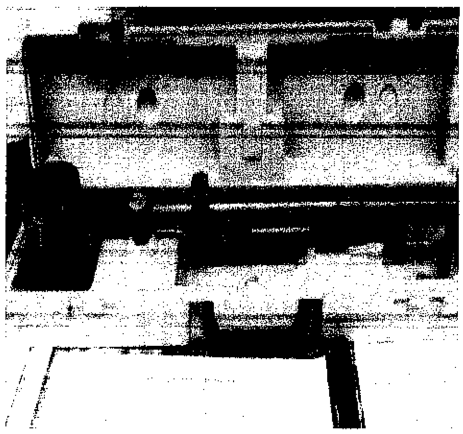


Figure 7: Mud balance

Figure 8: Viscometer

3.1.2 Injecting MR Fluid

When the drilling fluid was ready, the time for injection of a MR fluid had come. MR fluid was added to the drilling fluid according to the outline of experiment, in which the concentration of a MR fluid increases in each trial. Starting with 20ml to 60ml, concentration of our fluid inside the mud was increased.

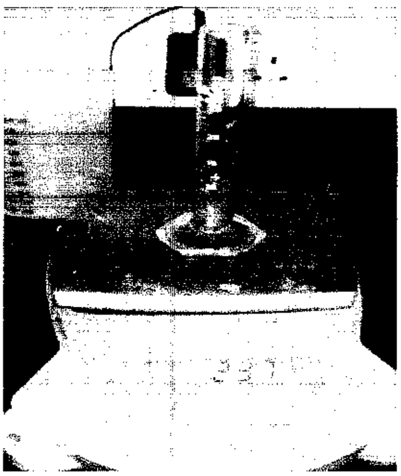


Figure 9: MR Fluid

3.2 APPARATUS

3.2.1 Magnetic Flux Generator

Very important part of this experiment was to achieve desired magnetic flux which will be enough to make our MR fluid added mud become gel. This magnetic field was achieved with help of magnetic field generating equipment and the level of magnetic flux was measured with help of Gauss meter. Coiled metallic equipments from each side of the cup generated magnetic flux. After that, the magnetic flux will be controlled by equipment. Desired 2 Tesla reading was reached on the Gauss meter and the equipment was ready for exploitation.

Magnetic field surrounding the cup was aimed for moving the iron particles inside the MR fluid, by that letting our fluid to expose its best qualities inside the equipment. All of these objectives were achieved by using the magnetic field inducing equipment, which was taken from the Electric and Electronics Engineering lab.

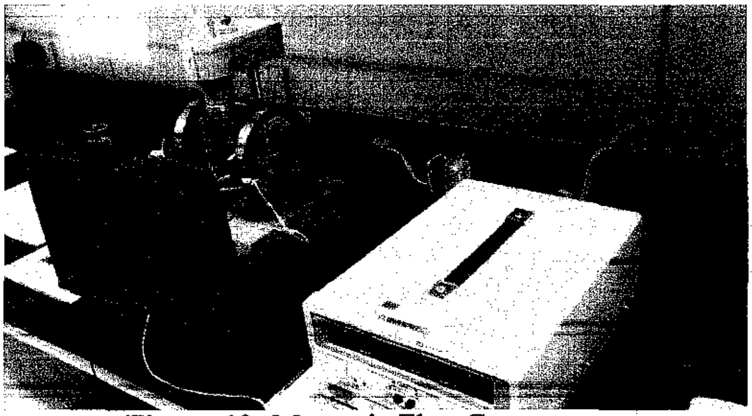


Figure 10: Magnetic Flux Generator

The equipment was set and was ready to be exploited. The reading of 2 Tesla was achieved on the Gauss meter, which was decided to be the optimal magnetic flux for the experiment. You can see in the Figure 11, how the magnetic flux was achieved. This magnetic field was the key for MR fluid`s gel strength increasing and enabling it show its potential in this experiment. When cup will be placed in heating chamber, magnetic field will surround it.

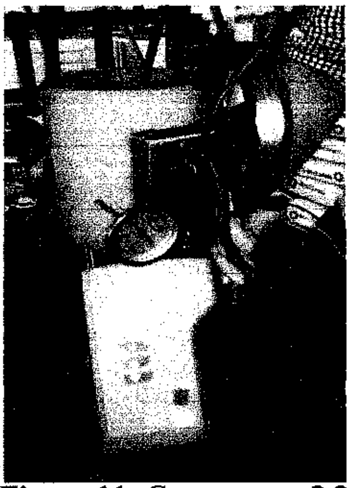


Figure 11: Gauss meter **3.2.1**

3.2.1 HTHP (high temperature-high pressure) Filter Test

HTHP filter test is the best equipment for measuring the filter cake thickness, fluid loss and considered as one of the hardest tests to handle in drilling fluids laboratory on drilling sites. It helps to simulate the behavior of the fluid in the wellbore, when there is a high temperature and high pressure applied on it. The principle of HTHP test is to fill the cup with the specific fluid and locate it inside the heating chamber, after which high pressure is applied. At the end of the session, there would be no fluid left and only the remaining of that mud, which had formed a filter cake. There are several impacts of the results from this test that should be taken under consideration.

Formation damage: If the drilling mud does not have good fluid loss property, fluid with small particles in drilling mud can be invaded into formations causing the formation damage. If the well is severely damaged, it will not be able to produce after perforation. This situation will heavily affect the profit of oil companies.

Differential sticking: The drilling fluid that has bad fluid loss will form a very soft and thick mud cake across the permeable formations. It can lead to differential sticking incident because the contact area between formation and drill string is increased.

Torque and drag: A thick mud cake across porous zones can be easily formed because the drilling mud has high fluid loss values. The thicker of mud cake is, the more torque and drag are experienced while drilling and tripping operation.

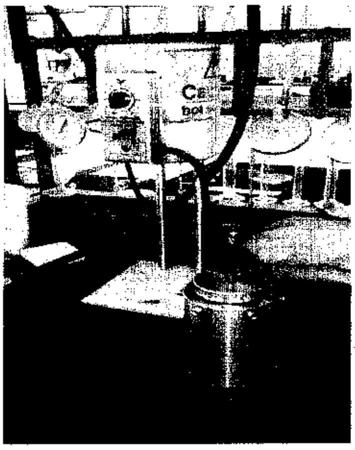


Figure 12: HTHP Filter Test Equipment

3.3 PROCEDURE

HTHP filter test equipment is very essential id drilling industry and it should be used very carefully, because high temperature and high pressure are involved. So, in order to get an excellent result without errors and damaging yourself, there are steps that should be followed, while using this equipment.

Loading the filter cell (numbers matching all the assemblies, cells and valves are illustrated in Figure 13 below)

1. Stir the drilling fluid sample 10 minutes with a high speed mixer.

2. Unlock the cell plate assembly (8) by loosening the three locking screws (1).

3. Remove the cell plate assembly (8) by rotating it to align the slots and pulling it out of the cell (7).

4. Close (Turn Clockwise) the valve (5) attached to the cell (7).

5. Position the cell with the open end up. A jar or beaker may help hold it.

6. Fill the cell to within 1/2 inch (1.3 cm) of the "O" ring groove.

7. Place one circular disk of filter paper in the groove just above the sample.

8. Place "O" ring (3) on top of paper.

9. Make sure valve (5) on the cell plate assembly is open, (Turn Counterclockwise)

10. Place cell plate assembly over the top of the cell and align then engage the locking lugs.

11. Evenly tighten cap screws (1) finger tight.

12. Close valve (5) on the cell plate assembly (Turn clockwise).

13. Invert loaded cell assembly with cell plate assembly down, placing it in the heating jacket.

14. Transfer the thermometer to the cell thermometer well.

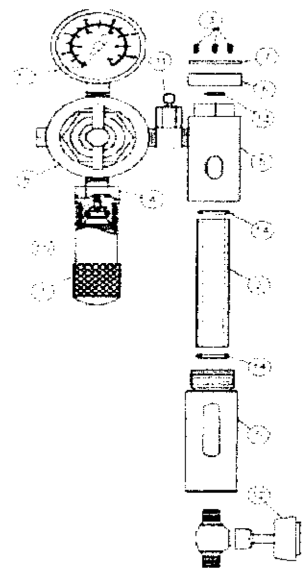


Figure 13: HTHP equipment

Pressurizing the Filter Press

1) Make sure the high pressure regulator tee screw is backed out, then place CO_2 cartridge into high pressure regulator assembly and tighten cartridge holder until cartridge seal is punctured.

2) Lift locking ring (4) on regulator assembly and place the regulator assembly onto the slip coupling on the top of the cell assembly and release lock ring. The high pressure regulator assembly is now ready for use.

Temperature of 350 F was used in this experiment and this information was useful in choosing the guideline for equipment exploiting. High temperature tests must be performed with the use of the back pressure receiver.

Run high temperature tests as follows:

1. Attach the back pressure receiver to the bottom of the cell plate assembly. Push down on locking ring on the top of back pressure receiver, and then slide the top of the back pressure receiver over the slip coupling on bottom of the cell plate assembly.

2. Make sure the back pressure receiver regulator tee screw is backed out (turn counterclockwise). Verify the bleed valve is closed (turn clockwise). Place a CO_2 cartridge into the back pressure receiver cartridge holder and tighten until cartridge seal is punctured.

3. Make sure both the top and bottom cell valves are closed. Turn top regulator tee screw (clockwise) to 100 psi (689 kPa).

4. Turn back pressure regulator tee screw (clockwise) to 100 psi (689 kPa).

5. Open top cell plate valve one full turn. This will pressurize the cell; eliminate boiling of water based samples heated above 212 oF (100 oC).

6. Monitor the cell temperature by observing the thermometer in the cell thermometer well. When the cell temperature reaches the test temperature, the filtration test may be started. Observe the correct thermostat setting by the heater cycling off and on. This is indicated by the red light going off and on.

7. Increase the pressure of the cell pressurizing unit to 600 psi (4134 kPa) or other desired test pressure and verify the back pressure is 100 psi (689 kPa) or as desired for the test.

8. Open bottom cell valve at least one full turn. Start timing the test. Filtration time is usually 30 minutes.

9. If the receiver pressure rises above its setting during the test, cautiously reduce the pressure by drawing off a portion of the filtrate, maintaining the correct differential. Maintain the selected temperature. Continue for 30 minutes or other test period.

Gantt Chart

Timelines for FYP 2

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Project Work Continues								Mid-Semester Break								
2	Submission of Progress Report									●							
3	Project Work Continues																
4	Pre-EDX												●				
5	Submission of Draft Report													●			
6	Submission of Dissertation (soft bound)														●		
7	Submission of Technical Paper														●		
8	Oral Presentation															●	
9	Submission of Project Dissertation (Hard Bound)																●

● Suggested milestone

□ Process

CHAPTER 4

RESULTS AND DISCUSSION

4.1 DATA GATHERING AND ANALYSIS

After the experiments were completed, the data from all the trials were compiled and the results were taken. Firstly starting with results from the trials, where there was no MR fluid used and the trial with MR Fluid mixture.

4.1.1 Fluid loss

HTHP Test was without the MR fluid and magnetic flux was held in order to get results for fluid loss rate and filter cake size.

300 ml of our drilling fluid was placed in the HTHP filter test. Filter cake thickness at the end of this session was measured to be 0.7 cm and the fluid loss during the experiment was measured as 38ml. It means that, 32 ml of fluid was evaporated, pressurized and let out to the beaker. Filter cake size of 1.3 cm was taken as the set point for following trials, where MR fluid and magnetic flux would play their roles. According to this data further information and experiment readings will be interpolated, investigated and compared.

After getting results for the trials without MR fluid, HTHP tests with MR fluid and magnetic field were conducted. By increasing the dosage of MR fluid in each trial from 20ml to 60 ml data for fluid loss were recorded for further comparison.

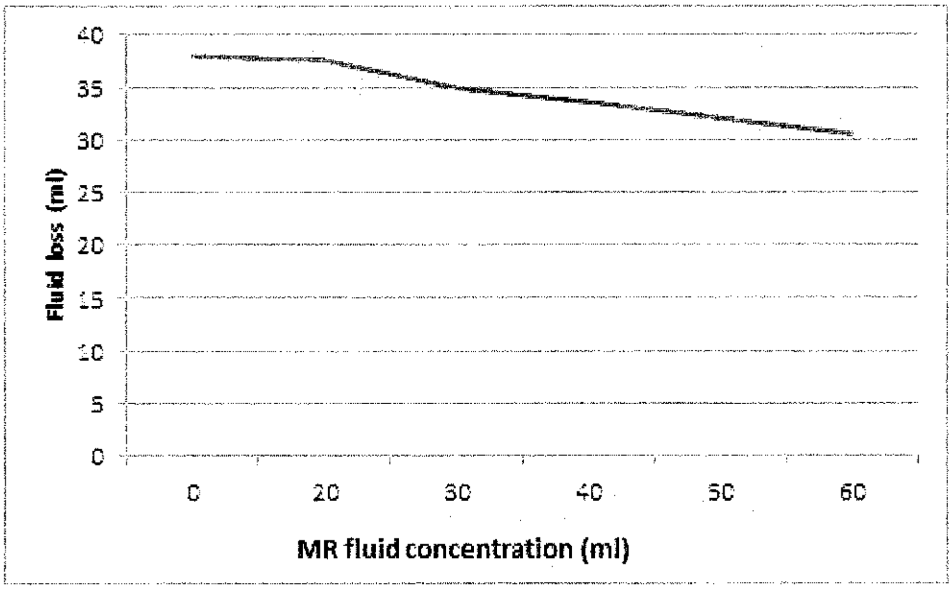
Concentration of MR fluid	20ml	30ml	40ml	50ml	60ml
Fluid Loss	37.5ml	35ml	33.5ml	32ml	30.5ml

Table 2: Fluid loss decreasing with an increase of MR fluid concentration

This data indicates that with increasing MR fluid concentration there is a tendency of fluid loss decreasing. This behavior can be explained by the fact that, iron particles inside the MR fluid activate when magnetic flux is applied and because of that our mud becomes more viscous. The gel form, which is taken by our mud, increases the boiling point. Molecules become harder to separate and thus thicker composition of MR fluid injected mud boils slower than the mud without MR fluid. The temperature inside the chamber is 350 F. When diesel starts evaporating and condensing into the cylinder there is a rate and volume that should be considered. In the fluid with no MR fluid there is no outer effect from magnetic flux, which let the major fluid (diesel) to boil in the pattern it is used to in standard conditions. But, when there is MR fluid added to the fluid, iron particles inside the mud start to activate due to applied magnetic field, therefore transform our mud into gel form. In the gel form fluid becomes more viscous, though making it harder for molecules to apart from each other. This intermolecular strength leads to less fluid loss in samples with MR fluid injection. And from the readings of these experiments this can be concluded:

- MR fluid enables better fluid loss property for the mud

- Magnetic flux in combination with MR fluid leads to less fluid loss, because of its ability to transform into gel



Graph 1: Fluid loss (ml) vs. MR fluid concentration (ml)

4.1.2 Filter Cake Thickness

Filter cake thickness was measured after each of the trial throughout the experiment and data was recorded. Thin impermeable filter cake is a desired result for HTHP tests and our experiment showed variety of filter cake thicknesses and conditions. If the fluid loss property of the fluid is good, the filter cake as was mentioned should be thin, impermeable and in good conditions. Every trial with MR fluid addition was tested for filter cake condition. 1.3cm of filter cake was concluded after the trial without the MR fluid and this data was compared to other trials. The decrease in filter cake thickness was observed along with slight worsening of the quality of the filter cake. This worsening can be considered as negligible, because the quality was lacking from the filter cake of a mud without MR fluid too.

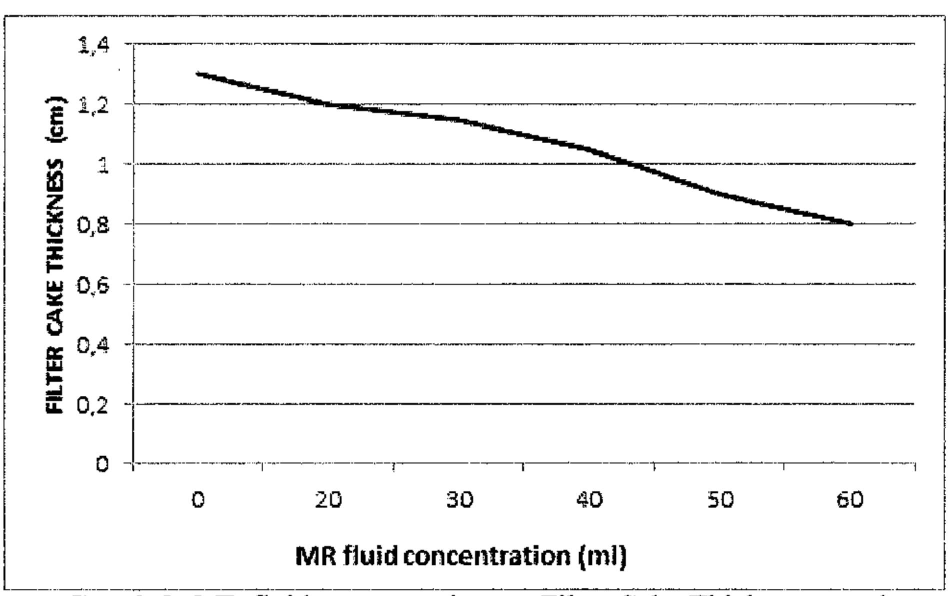
Figure 14: Filter cake after trial without MR fluid

Concentration of MR fluid	0ml	20ml	30ml	40ml	50ml	60ml
Cake thickness	1.3cm	1.2cm	1.15cm	1.05cm	0.9cm	0.8cm

As it can be observed on the table above, there is a slight decreasing of filter cake size. This is due to MR fluids ability to transform into gel and by that increasing the boiling point. As this happens, there are less depositions of filtrate at the end than it is with less MR fluid concentrated sample or a sample with no MR fluid in it. By the rule, it is considered that thinner filter cake with good impermeability is good property for the drilling fluid. But, there can be various expectations from filter cake thickness depending on the structure of the formation or drilling conditions. Desired filter cake thickness is determined by Drilling Engineers prior to the drilling after taking into account every possible variant and the structure of the formation. In this project the feasible tests are held and the main idea is to observe the performance of the MR fluids in remedying the loss of circulation. We have witnessed that increasing of MR fluid concentration decreases the fluid loss, which is a positive result for us. If mud cake thickness taken as set point, then there are some complications, due to earlier mentioned uncertainty and its dependence on structure of formation. If there are fractures of big size, then thicker filter cake can be estimated.

- Filter cake thickness decreases due to gel transformation of a fluid under effects of MR fluid.
- Comparing to results from a mud without MR fluid, sample with MR fluid has thinner filter cake.

If the question of the quality of the filter cake: as it is shown in Figure 14, the impermeability isn`t high. This can be explained with restricted possibilities in choosing the major fluid of the mud.



Graph 2: MR fluid concentration vs. Filter Cake Thickness graph

CHAPTER 5

CONCLUSION AND RECOMMENDATION

To conclude this project the importance of fighting back the loss of circulation should be mentioned. It is estimated that lost circulation cost the industry around $800 million per year, while the lost circulation products could represent as much as $200 million. Moreover, lost circulation has even been blamed for minimized production in that losses have resulted in failure to secure production tests and samples, while the plugging of production zones has led to decreased productivity.

The purpose of this paper is to explain how to prevent or remedy such drastic problem as lost circulation by using new technology of MR fluids. It is a completely new approach in an oil and gas industry. MR fluids commonly known as Magneto rheological fluids are suspensions of iron particles in liquid. Whenever these particles get contact with magnetic flux their gel strength increases, by that aiding in filter cake formation. Depending on desired concentration, measured amount of MR fluid will be added to the drilling mud prior to be pumped into the wellbore. The main objective is to induce magnetic flux to mud which was treated my MR fluids during the drilling through permeable formation or whenever the lost circulation was induced by forming large fractures in formation. Gelling of the drilling fluid will lead to high resistance towards fluid flowing into formation, by that helping in prevention or remedial of the lost circulation problem.

At the end of this project I was able to understand the concept of lost circulation and had familiarized with HTHP equipment. By interpreting the data and results that I got at the end of the experiment it can be said that, MR fluid is new approach in drilling operation and has to be enhanced to more efficient ways, but the first step towards the prevention and remedying of the loss of circulation with help of MR fluid has been taken. It can be concluded like this: the fluid loss is controlled better with MR fluid, even if the change is not significant. In addition to this, this should be added: filter cake thinning throughout the experiment is directly proportional to increase in MR fluid. Iron particles inside the MR fluid increase the gel strength, which on the other hand increases the suspension of solids inside the drilling fluid and increase viscosity. When viscosity is increased the fluid loss decreased, because in HTHP filter test the evaporation of diesel takes place. This fact, leads us to conclusion that with MR fluid the fluid loss decreases.

In industry, there should be made some enhancements. For example: using more accurate hi-tech technologies in calculating the fluid loss. HTHP test despite its popularity has downsides, because it can`t fully generate the down hole condition, thus some errors may had occurred. In drilling operation when there is a loss of circulation indicated, every second plays vast role in saving the wellbore and money. So, when MR fluid is mixed with drilling fluid and circulating inside the wellbore, then it can help to rapidly increase viscosity, by that help to remedy or in other case give some time for brainstorming. This gap of time is very important in drilling, because every second there is fluid lost and when there is a chance of having a break before tackling a problem in major way, why can`t we use MR fluid and buy some of that time? Of course, this opens up more doors for exploring and this area is very perspective and wide.

Advanced computer based technology would assist this project, because every centimeter and milliliter are crucial. Magnetic flux equipment can be changed into more advanced equipment in order to get exact data and be able to change the magnetic flux. Magnetorheological fluids are yet to be introduced to drilling industry and this first steps show hope towards the future of MR fluids in this sector. This project showed me how important it is to tackle the problems of lost circulation nowadays and that MR fluids can be helpful.

REFERENCES

[1] *Development of the three segment hydraulic model for cuttings transport in horizontal and deviated wells*, Hyun Cho, Norman Oklahoma, 2001

[2] *Drilling Practices and Sweep Selection for Efficient Hole Cleaning in Deviated Wellbores* D. J. Power, SPE and C. Hight, Baroid, a Halliburton Company, D. Weisinger, SPE, and C. Rimer, SPE, Vastar Resources Inc. 11-13 september 2000

[3] Neal J. Adam. *Drilling Engineering. A Complete Well Approach.* Penn Well Publishing, 1985.

[4] Amoco Drilling Manual

[5] www.maths-in-industry.org/miis/135/1/cuttings.pdf

[6] http://www.osti.gov/bridge/purl.cover.jsp?purl=/822109-rCPNSj/native/822109.pdf

[7] http://www.slidefinder.net/7/7_drilledcuttingtransport/32626344

[8] Sweatman, R. Faul, R., Ballew, C., "New Solutions or Subsalt-Well Lost Circulation and Optimized Primary Cementing", SPE 56499, 1999 SPE Annual Technical Conference and Exhibition, Houston,Texas (October 3-6, 1999)