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Evaluation of Coffee Dregs Performances as Lost Circulation Material (LCM) by Rheological & Filtration Loss Properties Test

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***Abstract*- One of the drilling problems is lost circulation, either in offshore or onshore operations. LCM (Lost Circulation Material) is needed in overcoming these problems, with the material variant, size and product making the company can choose as needed, and everyone is able to do it. Coffee production in Indonesia is quite a lot, 774.60 thousand tons in 2021. Besides being easy to obtain, the economic factor and synergy between the Oil and Gas Industry and the Coffee Industry in Indonesia. Pilot tests were conducted with 0ppb, 10ppb, 15ppb and 20ppb of Coffee Dreg in the Water-Based Mud (WBM) by considering Rheology & Filtrate Loss Properties. The affected parameters as follows for pH, fluids density and filtrate loss are decreased, PV/YP and Gel Strength are increased, potentials and need a further improvement as well.**

Index Terms- Loss Circulation Material (LCM), Offshore Drilling, Water-Based Mud (WBM), Rheology, Coffee.

I. INTRODUCTION

The background to the emergence of this research is the author in addition to being involved in the drilling industry, but also engaged in the coffee industry, so that it starts from the thought and relationship between the material (coffee) that is preferred with the condition of drilling problems such as lost-circulation.

This research focuses on the utilization of coffee dreg as Lost Circulation Material (LCM). The function of LCM to date is very important in oil and gas, either drilling or workover and well services, with the use of Synthetic-Based Mud (SBM) or Water- Based Mud (WBM) sludge. This paper discusses the performance of the coffee dreg conducted by pilot test as LCM taking into account aspects of Rheology & Filtrate Loss Properties.

Some literature and research also innovated on LCM or filtrate loss control with common materials around us, like sawdust with a mixture of coconut shells and husks [5], sugarcane as LCM [3], durian skin [4], and rice husk [1], an example. Especially at this time, author's using coffee dreg from the coffee puck from espresso machines, and until now have not found publication of the use of coffee dreg as LCM.

II. THE CHAIN OF RESEARCH

This study combines several processes from the coffee dreg out of the extraction machine until the pilot test is completed, some of the things that are wrapped in this study as follows:

1. More coffee dreg in less-chance to utilization, even though in large volumes.
2. For this pilot test, samples are processed using arabica coffee in Indonesia. The next opportunity is open to using species, varieties, post-harvest processes, and other roast profiles.
3. Target 0% water content with natural drying, so as not to have an impact on the age of the material at the time of storage.
4. Conduct testing in the WBM (Water-Based Mud) Phase by considering size, Rheology & Filtrate Loss such as pH, Mud Weight, PV, YP, Gel Strength and Filtrate Loss in accordance to API Standard RP 13B-1 [9] and ISO 10414 [10].

III. COFFEE DREG UTILIZATION

This research was conducted with the aim of adding a list of references to alternative LCM in the world of drilling. So many opportunities for utilization in coffee in general, it does not mean it cannot be harmonized with the drilling industry. Of course, the goal in this study is not FOR commercialization, but especially to know the effect and performance of coffee dreg on its quality as LCM, namely COFFEESEAL.

A. Coffee's Industry in Indonesia

Indonesia's Coffee Industry until 2022 is getting more advanced, the coffee business chain in Indonesia can be said to be doing well. Regional, national scale competitions and even participating in some international coffee events are intensive. Therefore, the chains of coffee businesses started from plantations and processing, roastery, coffee shops to home brewers runs together. Almost every day people buy coffee, anywhere, so the coffee grounds are abundant and surveys say the utilization of coffee grounds is still very low. So that if the point of view can be maximized, utilization opportunities will be wide open if the scale seen is a large market (abundant raw materials).

Economically, it has not yet been determined how much the coffee grounds will cost. However, if the pulp is not used, the value of the profit to get raw materials becomes reliable. Another interesting thing is, TKDN (Domestic Component Level) can touch the 100% mark if the coffee collected with certain criteria (not all grounds are acceptable) comes from Indonesia (not imported coffee). Therefore, the contribution of the community and the form of synergy with the producers will be well established and flexible. Curation to control the materials (coffee dreg) can also be done directly because of the affordability of the location.

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B. Coffee Dregs Processing for as LCM

The selection of coffee is carried out directly on the resulting dreg. The result is a coffee puck with 15-19grams. The used coffee at this time is without going through a special process, namely coffee selection first, such as a source or selected supplier, a special post-harvest process, special roast profile, of course the quality aspect will not be the same if it is done. But it is ensured that coffee becomes through a recorded management process.

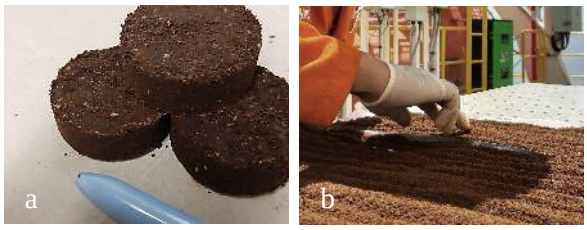

Figure 1. Coffee Puck (a) and dreg's sun drying (b)

The initial activity after the dreg is produced is to destroy the shape of the puck into sand in order to uniformize the shape and size in a large mount. Then the dreg dried by relying on solar irradiation without using special technology as a dryer to remove the %water content. But changes from high to dry water content are clearly visible in terms of weight, color, texture and aroma, so coffee can be more durable if stored on packaging at ambient (normal storage) and not too risky to reduce the density.

LCM certainly requires control over size, therefore Sieve Laboratory Test with 120mesh (125 microns) to separate finer particles from those that are held. This avoids the solubility of fine size against mud when the pilot tests later, and finally the size of the coffee dreg used in the range of 125 until 250microns. The composition of this LCM is purely 100% coffee without any organic mixtures and other synthetic ingredients. This aims to find out the overall performance of coffee dregs against rheology and filtrate loss with Water-Based Mud (WBM), although in the concept of LCM is allowed to do combination of material's sizes on an LCM to be made, both fibrous, flakes, granules and blended [6].

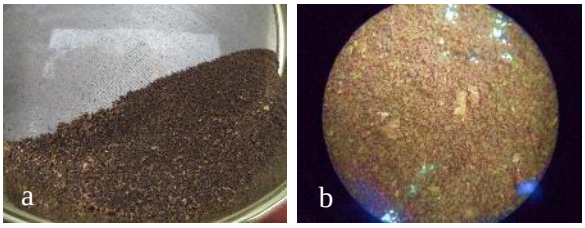

Figure 2. Sieve Shaker and dregs (a), and Microscope view's (b)

C. Mud Composition & Rheology

The drilling sludge used this time is water-based and polymer mud called Water-Based Mud (WBM). The selection of mud is based on consideration of the trend of the loss zone located in the oil and gas field where the pilot test is conducted, at intervals of 17-1/2" and 12-1/4" that use the mud, along with the emergence of the idea of using coffee grounds as LCM.

The properties and rheology of usage mud in this study are within pH around 8.8-9.0, Mud Weight in 9.0ppg, Plastic Viscosity (cp) in 8, Yield Point (lb/100ft^2) in 14, Strength Gel (lb/100ft^2) for 10 seconds in 5, Strength Gel (lb/100ft^2) for 10 minutes in 6, and the volume of Filtrate Loss (mL/30minutes) in 14mL. It's a fresh drilling fluid to be used in drilling in 17-1/2" hole section, consists of Sea Water, Caustic Soda, PAC-RE and Xanthan Gum Polymer [10].

D. Mixing and Shearing

The samples used in the pilot test were conducted on a scale of 350mL equalizing 1 barrel, and 1gr equalizing 1ppb. Mud samples without LCM mixtures were prepared for 1500mL for four test reps. First, 350mL with 0ppb LCM, second at the same mud volume as 10ppb LCM, third concentration increased to 15ppb, and fourth ended at 20ppb. Mixing between sludge is done not from the beginning of the sample prepared, in advance and mixed with Hamilton HMD200P-CE Mixer against samples that have been divided into four servings. After the vortex is formed LCM is inserted according to the session of testing each concentration. Except for s0ppb which is not mandatory mixing with this instrument because it is without LCM [9].

Figure 3. WBM and LCM mixing

E. Potential Hydrogen (pH) Test

pH testing is also carried out on samples that will be tested with Lutron 201, in addition to initial mud, but samples with various concentrations are also carried out. Basically, this expectation of pH values can lead to the acidic class, or remain in the alkaline class, because causes by Arabica's Species which used by acidity dominantly than other species such as Robusta by OAs (Organic Acids) and CGAs (Chlorogenic Acids) cumulatively [7]. Although it had been dried up to 0% of water content, the acidity is still stored inside the coffee grounds or dreg.

Therefore, the change in pH value between concentrations can be seen from 0ppb, 10ppb, 15ppb to 20ppb, and fluid determination steps can be immediately done such as the addition of $CaCO_3$ to restore to a degree of neutral or alkaline acidity. But in this test, no addition of $CaCO_3$ was done so that it can be seen in its entirety the effect of coffee dregs on mixed fluids.

Figure 4. pH Testing using Lutron 201

F. Mud Density Measurement

Identifying the density of mud is very important, considering the function of the drilling sludge is quite strategic

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and critical such as primary well control against formation pressure and hydrostatic, hole cleaning, and drill bit lubrication, density in the program mentions to 9.0ppg Water-Based Mud (WBM), on reference other drilling locations with the same mud phase ranges from 9.8-10.5 even 11ppg [2]. The value is pure without the LCM mixture weighed with Fann 140 Regular Mud Balance, and any additional concentration will be weighed. The effects of LCM can make the density of mud reduced or increased, and the condition is influenced by the composition of LCM.

Figure 5. Mud Weight (ppg) measurement

G. Mud Rheological & Properties

This test in addition to considering the effectiveness and distribution of plugging to rock pores, pH and density, but its impact and effect on aspects of rheology are likely to raise questions about the following parameters:

1. What is the effect of addition on the pH of the mud and what is the lowest value?
2. What is the density value of each concentration?
3. What is the PV/YP value at the addition of concentration?
4. Is there late potential?
5. What is the condition of Gel Strength after mixing LCM?

Figure 6. Viscometer with mixed sample

Testing with Fann Viscometer against mud rheology uses several parameters, the volume requirement, temperature ranges from 120-150°F with the analogy of geothermal gradient, the more depth the Bottom Hole Temperature (BHT) will be higher. The addition of temperature can be adjusted to the conditions of the presence of drilled footage.

In addition, RPM adjustments are considered as drilling parameters and cells on the viscometer as drill strings. Its switchable started from 600 RPM-High, 300 RPM-Low, 200 RPM-High, 100 RPM-Low, 6 RPM-High and 3 RPM-Low for PV (cp) and YP (lb/100ft^2) data collectivity. Gel Strength is measured twice with 10s on a rotation of 600 RPM-High stops 10 seconds and restarts at the 3 RPM-Low setting. For 10minutes measurement it is equal to testing with 10 seconds measured, which distinguishes at the duration of the test stop from 600 RPM-High to the last 3 RPM-Low [11].

This reading sees the highest degree spike, with the analogy of a drill string starting to move back and gel breaking occurs. As low as the base temperature of the hole, the spike's reading will be higher than in high temperature conditions, and the breaking gel will be easier to do at high temperatures.

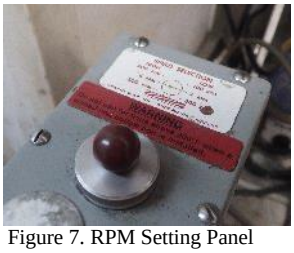

Figure 7. RPM Setting Panel

H. Filtrate Loss Test

The philosophy of this test system is how a particle (coffee dreg) can cover the rock pores on the well wall, so that lost-circulation conditions can be controlled and controlled properly. PPT (Particle Plugging Test) is done with LPLT (Low Pressure Low Temperature) for 30 minutes which in this test requires a sample of mud mixture with LCM, and paper filter as a plugging zone on particles that are given pressure as much as 100psi with $_{CO2}$ cartridge. The tests also compared initial mud with various concentrations from 10ppb, 15ppb and 20ppb against 9.0ppg MW with the initial invasion fluid rate at 14mL. Expectations of this test can provide graphs of decreased invasion, the reaction of coffee chaff with granularity of coffee dreg becomes the focus of effectiveness in this pilot test.

Figure 8. Low Pressure Low Temperature (LPLT) Testing

Other literature uses various LCM models to obtain the lowest invasion values, based on the shape of materials such as fiber material, flaky, granule, slurry and blended. This can be fore to be in subsequent experiments, most importantly in determining it can be based on the porosity of rocks that are considered loss zones, the mud used and the material action-reaction relationship [3].

I. Mud Cake

Filtrate Loss (API) test results with PPA-LPLT (Particle Plugging Apparatus Low Pressure Low Temperature) in addition to producing volume invasion fluid also produce mud cake data with mud composition and LCM that reacts. Visually it will be seen the distribution of particles in the filter which is analogous to a rock wall in a borehole, if tight then almost the entire pores are closed and should be directly proportional to the invasion fluid value.

But it is necessary to calculate the thickness of the cake formed and test the bending on the mud cake to ensure limited fault or not, where the arch is analogous to the shape of the inside of the wellbore. An even distribution does not guarantee that the value of the invasion will be low, the size of the grain and the combination of size and material become one of the

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influential factors, although it returns to the physical properties of the rock [8].

IV. PILOT TEST

The pilot test is conducted once at the Mud Laboratory with the following duration of testing.

TABLE 1. PILOT TEST TOTAL DURATIONS

Process	Equipment/Method	Time (min.)
Coffee Dreg Drying	Natural Sun Dried	2880
Sieve Shaker 120mesh	BBS Lab Test Sieve	120
Shearing & Mixing	Hamilton HMD200P-CE	15
pH	Lutron pH Meter 201	8
Fluid Density (ppg)	Fann140 Reg. Mud Balance	12
Mud Rheological	Fann Viscometer 35A	120
Filtrate Loss mL/30min	Filter Press API (PPA)	150
Mud Cake (mm)	Visual & Bend Test	130
TOTAL	**Minutes**	**3435**
	Hours	**57,25**
	Day	**2,39**

Sources: Author, 2022

a. pH Testing for Mixed Material

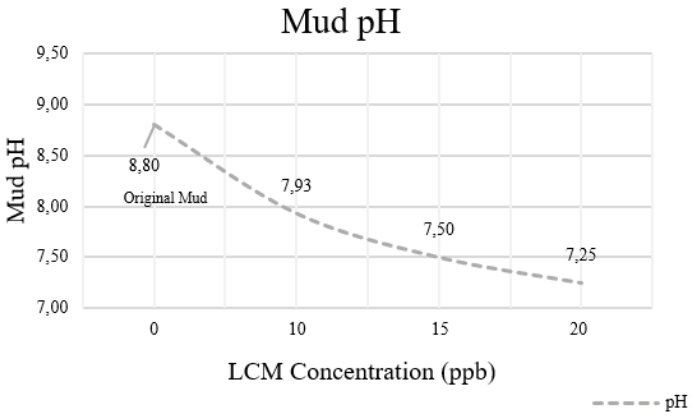

Figure 9. Graphic of pH Test Results

PH measurements in the sample are indispensable to the reaction performance between the mud and the LCM. The mud used is WBM with a pH of 8.8-9.0, the value is alkaline, where mud with a degree of acidity is more effective in reacting with other additives. Another effect if the mud is acidic, the potential for asthma against metal objects will be able to cause corrosion and fragility for a long time. The addition of LCM shows a graph where the higher the concentration given, the lower the pH obtained. But this is relatively common, with the characteristics of coffee used to have acidity and organic matter is more likely to provide acidic properties. To overcome the low pH, $CaCO_3$ or NaOH can be added as a function of neutralizing or restoring the acidity level according to the mud program.

b. Mixed Material Density

The test resulted in the value that the density of mud mixed with LCM decreased with a decreased interval in the initial mud with a concentration at 10ppb (0.5ppg), for 10ppb and 15ppb observed to be stable without change, and 15ppb to 20ppb having an interval of 0.1ppg. This can occur after the reaction of coffee with acidity and fast mixing also by particles characteristic. Therefore, in the process there is a decrease in density. When compared to the density of seawater in Indonesia with a value of 8.4-8.5, the concentrations of 10ppb, 15ppb and 20ppb are in the same ranges.

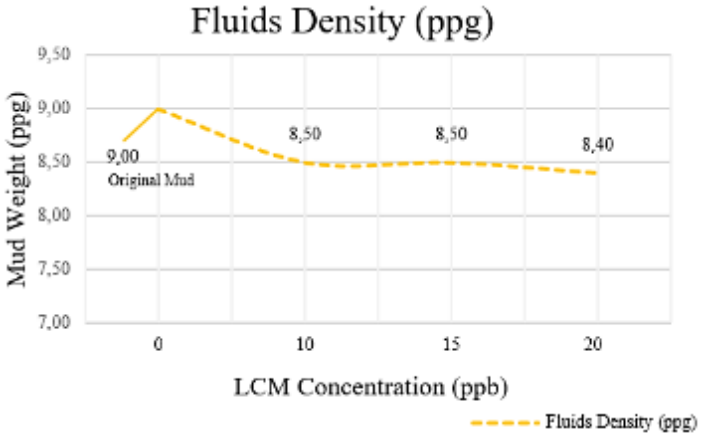

Figure 10. Graphic of Mud Density

In addition, weight becomes very necessary when mud mixing to deal with lost-circulation. Heavy-enhancing materials that can be added such as Barite or weighting agents. Another effect if the mud gets lighter is the ability to maintain pressure in the well between formation pressure (psi) vs hydrostatic pressure (psi). Density is also needed in keeping the cutting in the well not settling massively, if the density of the mud can be greater than the density of cutting or solid.

c. Rheological: PV/YP & Gel Strength Analysis

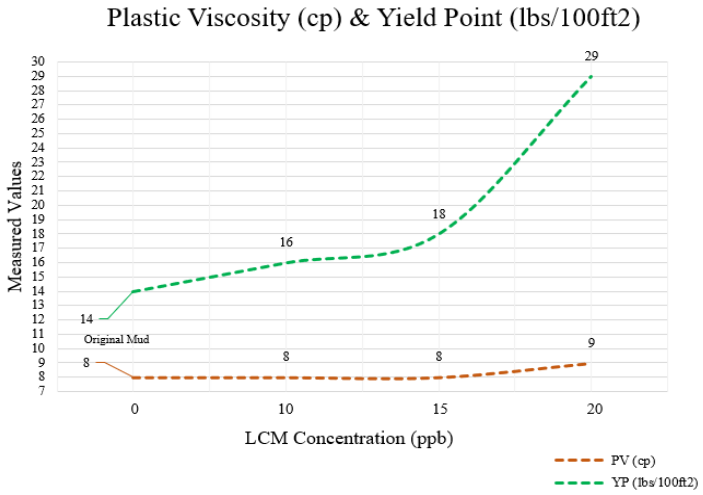

Figure 11. PV/YP Testing Results

The results of rheological testing of mud containing LCM showed an increasing trend since 0ppb (8cp), 10ppb (8cp), 15ppb (8cp), and 20pbb (9cp). Resistance to the flow of these PV values tends to increase along with increasing LCM concentrations. Solids in LCM do remain and are insoluble, it causes PV prices to increase, similar to drilling activities against formations, as depth and cutting are produced, PV can increase due to friction between the mud and the solid. The recorded data with mixed LCM had started for 10ppb with 600/300RPM (32/24), 200/100RPM (20/16), and 6/3RPM (8,7). 15ppb with 600/300RPM (34/26), 200/100RPM (24/20),

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and 6/3RPM (10/9). The last is 20ppb with 600/300RPM (45/36), 200/100 (34/28), and 6/3RPM (16/12).

The price of YP also increased and proved to be the higher the concentration of LCM, the price affects the Yield Point number, where in the determination of the price of YP can be calculated based on the number recorded at 600 RPM reduced by the number at 300 RPM. 0ppb shows values of 14lbs/100ft^2, 16lb/100ft^2 at 10ppb, 18lb/100ft^2 at 15ppb, and 29lb/100ft^2 at 20ppb. High YP values indicate a non-Newtonian effect where cutting can be lifted well to the surface through the annulus. But if YP is to be lowered, the clay-based deflocculant can be an alternative, or the addition of lime to the mud or using decanter centrifuges. For Gel Strength (GS), the higher record attached on 20ppb, because of the particles while the string has rotation, need a force higher than 10-15ppb LCM to break gels in 120°F (48,88°C) from static condition. 10 seconds measured gradually increased from 9lb/100ft^2 (10ppb), 11lb/100ft^2 (15ppb), and 20lb/100ft^2 (20ppb). It makes sense when the particulates by LCM are filling the mud which can be affected for rheological purposes. For 10minutes in the same methods like 10 seconds testing, the difference is in waiting time to re-run the speed to 3 RPM with a low motor (after 10minutes waiting) to break the gel. Therefore, the string needs more force to break gels (the longer time static and the temperature is constantly or decrease, the gelling reactions the higher it is).

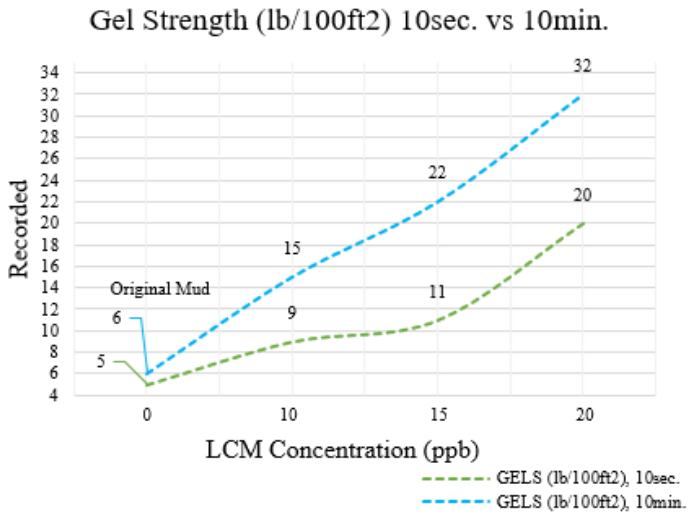

Figure 12. Gel Strength (GS) in 10seconds vs 10minutes

d. Filtrate Loss (API) with PPA-LPLT

After rheology testing is completed, with the same sample at each concentration the last test is carried out, namely Particle Plugging Test (PPT) with Fann Low Pressure PPA (Particle Plugging Apparatus). 350mL samples at both 0ppb, and 10ppb, 15ppb, 20ppb that already contained LCM were tested interchangeably. Each test is performed 30minutes since the 100psi pressure has been achieved and controlled so that the pressure remains constant for 30 minutes using the pressure of the CO_2 cartridge. The results showed mud without LCM had invasion fluids of 14mL, while at 10ppb (13mL), 15ppb (11mL) and 20ppb (10mL) respectively. The expected of invasion fluids volume on PPT results are smaller from the current test results, but another factors as determinants of intervals that have not been too far away can be caused by the distribution of particles with grain size and LCM composition. However, the graph of the decrease in each addition of concentration is certainly a positive thing in this experiment.

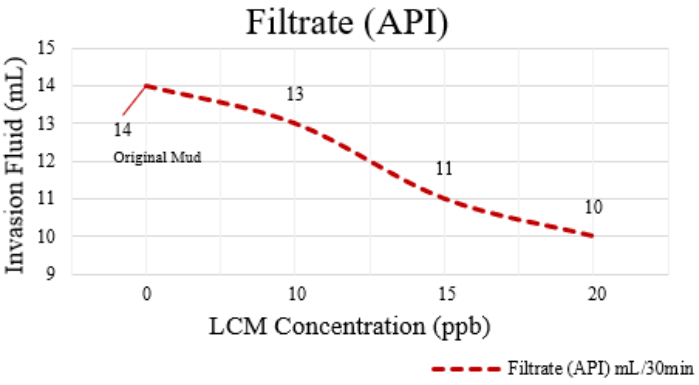

Figure 13. Invasion fluids by Particle Plugging Test (PPT)

Another result on the Particle Plugging Test is the Mud Cake, where the presence of mud cakes is located on paper filter discs located in the PPA chamber. What is visible this time is the thickness and flexibility of the cake attached to the paper filter. It is necessary that in fact, the cake responsible for sealing the pores is not loose and effective. Laboratory scale, curvature as a test of flexibility and simulation of diameter shape in drill wells. The results showed no abnormal sizing during the bend test, with a maximum mud cake thickness of 1.1mm at 20ppb.

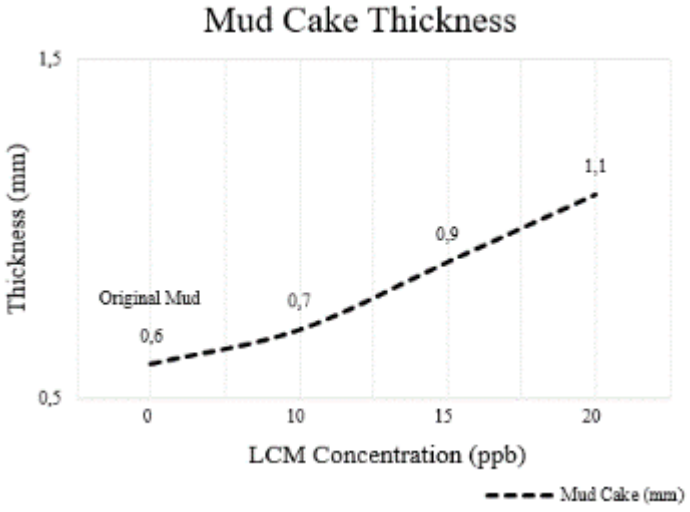

Figure 14. Mud Cake Thickness

Figure 15. Fluid's Sample (WBM & COFFEESEAL LCM)

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Figure 16. Mud Cake in 20ppb of LCM (COFFEESEAL)

Figure 17. Mud Cake in 15ppb of LCM (COFFEESEAL)

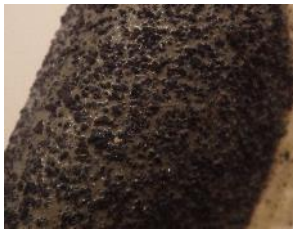

Figure 18. Mud Cake in 10ppb of LCM (COFFEESEAL)

Based on the appearance of the mud cake above, the area with 20ppb LCM is dominated by LCM (dark color) and the density of particles between grains is better than WBM (gray) between them. The concentration of 15ppb LCM still leaves some gray dots that are WBM, and the lowest concentration of 10ppb LCM is seen to be spaced between LCM and WBM space. Therefore, if it will increase plugging to suppress invasion numbers, grain size and material selection in the preparation phase is needed.

V. IMPROVEMENT

Based on pilot test experiments conducted from March 14-16, 2022 and the analysis thereafter created several ideas and notes for improvements and subsequent research opportunities. Some parameters have their own analysis where in the end the interrelationship between parameters becomes real in the evaluation for their development. It can be developed in subsequent studies, either done by the same researcher and author, or subsequent researchers interested as follows.

1. The selection of coffee grounds can be done by paying attention to the size of the grain from the last mill, either used alone at home or the results of consumption from the coffee shop.
2. The size of the grain so that it is not too fine and not too coarse. Too fine a size can lead to high solubility, so it can accelerate the rate of pH decline and requires alkaline material as a counterweight.
3. If the experiment this time is done with coffee from the Natural Post-Harvest Process, then the next experiment is better if it is produced from the Full Wash Process. Such consideration considers the combination of material shapes needed in increasing plugging, in this case coffee chaff in the Full Wash Process and subsequent wet hull and honey that is more than natural process, anaerobic natural anaerobic, etc.
4. Fibrous texture (coffee chaff) plays a role in providing a foundation on the texture of granule (coffee dreg) so that resistance and distribution can be better.
5. Coffee puck storage is better in the open air in the room and has been blurred which is useful to equalize concentration and humidity.
6. Drying done at two to three hours per day will be better, right at the duration of the scorching sun.
7. For a larger scale of production, it is better to use vibratory Sieve Shaker with a more diverse size separation and able to accommodate larger and stable quantities. This is able to make the COFFEESEAL (LCM) variant more diverse, COFFEESEAL Fine, Medium or Coarse.
8. Subsequent testing is wide open for other types of mud such as Synthetic-Based Mud (SBM).
9. The combination of the mixture during the pilot test can be added $CaCO_3$ as a balance of acidity degrees, this is related to pH. Another alternative to using Robusta Species (cocoa, nutty, bitter > acidity) than Arabica Species.
10. Roasting profile can be determined at Medium level or Light to Medium.
11. In anticipation of a decrease in mud density (lb/gal), the addition of a weighting agent is needed.
12. LCM composition arrangement between fibrous and granule can be tried to improve the quality of plugging to withstand filtrate loss and mud rheology on PV/YP and Gel Strength readings.
13. Mud cakes with fibrous and granule compositions (medium or medium to fine) are expected to get better in plugging or wellbore strengthening.

VI. CONCLUSION

Based on this study, the conclusions that can be given are as follows:

1. The use of coffee grounds and chaff as LCM has a good opportunity, data supports in the development of utilization to be better and feasible.
2. Testing taking into account Rheological and Filtrate Loss Properties is enough to scale up at this time.
3. Opportunity to use HPHT Test in LCM testing at the next opportunity.
4. The evaluation will be reviewed again as an improvement especially the decrease in mud density and plugging effectiveness.
5. The composition of 100% coffee is still in a high level of optimism, with the collaboration of coffee dreg with coffee chaff will have the opportunity to create more optimal results.

APPENDIX

Tabulation and Laboratory's Summary is attached on the last page.

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ACKNOWLEDGMENT

This research is purely on the basis of thought and initiative, with the aim of utilizing opportunities from coffee grounds that have never been tested in the Lost Circulation Material (LCM) Pilot Test, and the results obtained in this study is a part of science and technology. Hopefully, this research can be useful as a scientific field so that the next research can be done better.

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APPENDIX 1. TABULATION

Parameters	Model	Testing Duration (minute)	LCM Contentration (lb/bbl)			
			0	10	15	20
Coffee Dreg Drying	**Natural Sun Dried**	2880	√	√	√	√
LCM Sieve Shaker (mesh)	BBS Lab Test Sieve	120	120	120	120	120
Mud Type	KCl/Polymer	-	WBM	WBM	WBM	WBM
Initial Mud Vol. (mL)	-	-	350	350	350	350
Blend/Shearing	Hamilton Beach HMD200P-CE	15	5min.	5min.	5min.	5min.
pH	Lutron pH Meter 201	8	8,80	7,93	7,50	7,25
Fluids Density (ppg)	Fann140 Reg. Mud Balance	12	9,00	8,50	8,50	8,40
600/300	Fann Viscometer 35A	120	√	32/24	34/26	45/36
200/100			√	20/16	24/20	34/28
6/3			√	8/7	10/9	16/12
PV (cp)			8	8	8	9
YP (lbs/100ft2)			14	16	18	29
GELS (lb/100ft2), 10sec.			5	9	11	20
GELS (lb/100ft2), 10min.			6	15	22	32
Filtrate (API) mL/30min	Filter Press API (PPA)	150	14	13	11	10
Mud Cake (mm)	Visual & Bend Test	130	0,6	0,7	0,9	1,1
	Minutes	**3435**				
	Hours	**57,25**				
	Day	**2,39**				

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Appendix 2. Graphic's Summary