

Experimental Study of Coconut Fiber as a Fluid Loss Control Additive to Prepare an Eco-Friendly Drilling Fluid

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ABSTRACT

Fluid loss from borehole to formation is a prominent challenge that arises during drilling operations. Excessive fluid loss can lead to various issues such as formation damage, well-bore instability, reduced drilling efficiency, and increased operational costs. Chemical additives are used to improve drill-fluid sealing capacity and reduce fluid loss. Chemical additives create harmful impacts on the environment. This research presents an experimental study on coconut fiber to investigate its effectiveness as a fluid loss control additive. This study aimed to evaluate the potential of coconut fiber as a sustainable alternative to chemical additives. The experimental work involves the preparation of drilling fluids using varying concentrations of coconut fiber and evaluating their performance. Laboratory tests are conducted to measure filtration loss, rheological properties, resistivity, pH, mud weight, and sand content of samples. Four different concentrations of 0.5%, 1%, 1.5%, and 2% coconut fibers, particle sizes from 125 to 212 μm , are used in the test. The results of this study show that fluid loss is reduced with increasing concentration of coconut fiber. The coconut fiber acted as a bridging and sealing agent, creating thin, impermeable mud cake and minimizing fluid invasion. The findings highlight the potential of coconut fiber as an effective and sustainable option for mitigating fluid loss in drilling operation. The eco-friendly nature of coconut fiber adds to its appeal as a greener alternative in the petroleum industry. The outcomes of this research focus on environmentally conscious drilling practices and promote the practice of biodegradable materials in drilling operations.

Keywords: Drilling fluid, Fluid loss, Fluid loss control additives, Coconut fiber, Laboratory test.



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1. Introduction

Drilling fluid is an important component of the rotary drilling process. Drilling fluid used to transport cuttings from bottom hole to the surface, provide sufficient hydrostatic pressure to subsurface formations to prevent formation fluids from entering the well, support the wellbore wall until the casing can be set and cemented, lubricate and cool the revolving drill string and bit, and provide the bit hydraulic horsepower. Additionally, Drilling fluids are designed to reduce fluid loss to the formation, generate thin filter cakes that plaster the borehole's walls to prevent fluid leakage, and improve the well's stability (Agwu & Akpabio, 2018). Filtration loss from wellbore into formation is a common phenomenon in drilling operation. The liquid portion of mud enters into the formation's pore space and the solid portion of mud creates a cake in borehole wall, this phenomenon is known as filtration loss in drilling. Drilling fluid acts as a key well control method by keeping the hydrostatic pressure of the drilling fluid column greater than the formation pore pressure. The pressure disparity between the drilling wellbore and the permeable formation causes liquid to flow from the wellbore into the formation, forming an impermeable filter cake by leaving colloid particles of drilling fluid on the wellbore wall. In addition to preventing filtrate from leaking into the formation, which could cause formation damage, filter cake creation is important for the stability of the drilled wellbore (Azar and Samuel, 2007). Filtration loss causes decrease the volume of drilling fluid, formation damage by

clogging pore space, wellbore instability and it is a mechanism that contributes to loss circulation. Before mud cake form in wellbore wall some liquid enter into which reduce formation stability. This initial filtration is known as spurt loss (Kumar, 2010). Various types of chemicals and polymers are utilized in order to create a drilling fluid that meets functional requirements such as acceptable mud rheology, density, mud activity, fluid loss control property, and so on (Amanullah et al., 1997). Chemical material such as Bentonite, Polyanionic Cellulose Low Viscosity (PAC LV), Polymers, Resinex, Hydroxyethyl Cellulose (HEC), Carboxymethyl Cellulose Sodium (CMC), and Strach are used to control filtration loss (Basra Oil Company, 2009). These additives primarily assist in the acceleration of filter cake development and, as a result, restrict the overflow of drilling fluid into the formation pores (Egun & Abah, 2013). Due to the higher toxicity of oil-based drilling fluids, especially in environmentally sensitive places, environmental concerns have raised interest in adopting traditional water-based drilling fluids over oil-based drilling fluids. However, many of the commercially available drilling fluid additives are non-biodegradable and have little or no environmental awareness. Toxic chemical additives are now used in water-based systems. These additives, which include sodium hydroxide, potassium chloride, potassium sulfate, polyamines, chrome thinners, fluid loss additives, and others, are all hazardous to the environment and extremely expensive (Amanullah, 2007). When employed to manage

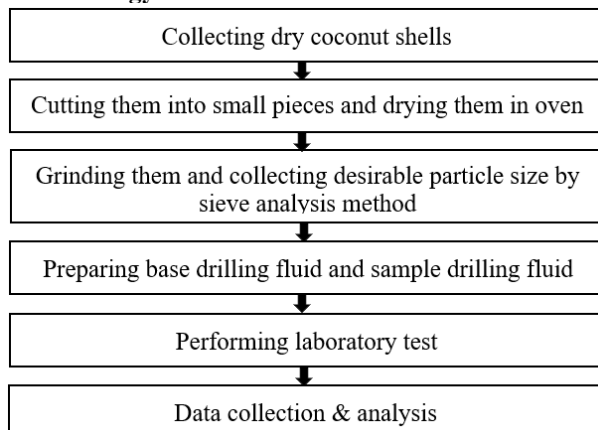
drilling fluid parameters, conventional chemical additives have significant adverse effects on the environment and worker safety. Commercially accessible additives are made of compounds that are not biodegradable and have negative environmental consequences when discharged (Al-hameedi, Alkinani, Dunn-norman, & Alshammari, 2019).

The main aim of the study is to control the fluid loss property of water-based drilling fluid by using coconut fiber. The objective of this research is to determine the applicability of coconut fiber to control fluid loss in water base drilling fluid. And, to determine the compatibility of coconut fiber with rheological properties of drilling fluid.

Many researches are conducted on filtration loss control during drilling process. The study of environmentally acceptable fluid loss control additives for drilling attained prominence in the late 20th century and has since developed. Due to growing environmental concerns and the demand for sustainable drilling techniques, more attention is being paid to creating ecologically suitable substitutes for conventional fluid loss control additives.

Okon et al., 2014 conducted research on rise husk to measure the fluid loss properties and mud cake thickness. The results of that research show that at a rice husk level of 20g per 350 mL mud, there was a 64.89% reduction in fluid loss. Rise husk is a fluid loss control additive that can be used in drilling fluids with a water basis. Another author Al-hameedi et al., 2019 do research on potato peel powder to find its rheology and filtration control properties. In this experiment researcher finds that YP and gel strength do not increase proportionately with the potato peel powder (PPP) concentration, indicating that a lower concentration of 1% to 2% should be employed for best results. PPP also significantly decreased fluid loss and mud cake thickness. Again Taylor et al. do an experiment in 2007 on walnut shell to estimate its rheological and filter loss characteristics. Findings of this experiment are that the ideal walnut shell measurement is 6 mm. The smaller shells of walnut are unable to hold the particles in suspension. Al-hameedi, Alkinani, Dunn-norman, Al-alwani, et al. in 2019 do research on filtration property of grass and find that compared to the starch material, the grass powder produced a more impermeable and thin mud cake and is effective in controlling volume loss. Another research on banana peel powder is done by Al-hameedi et al. in 2020. This research shows that rheological and filtration property of banana peel powder significantly enhanced the chloride content, filtration qualities, and rheological properties.

2. Methodology



3. Experimental Setup

Barite, Bentonite, Xanthan Gum, Sodium Hydroxide, and water are used to prepare the base fluid. Fig.1 represents all these component after weighing.



Fig.1 All components used in base mud preparation (Bentonite, Barite, Xanthan gum, NaOH respectively)

Table1 Composition of base drilling fluid

Additives	Quantities
Water	350 ml
Bentonite	12 gm
Barite	12 gm
NaOH	1 gm
Xanthan Gum	0.5 gm

Grinded coconut fiber are organized according to their size by sieve analysis.



Fig.2 Raw coconut fiber after sieve analysis (particle size $\geq 460 \mu\text{m}$, $215-460 \mu\text{m}$, $150-215 \mu\text{m}$ respectively)

Table 2 List of sample mud prepared for laboratory tests

Name of sample mud	Drill fluid composition	Weight Percentage of coconut fiber w.r.t base mud	Weight (gm) of coconut fiber	Particle size (micron) of coconut fiber
S1	BM+0.5% CF	0.5%	1.75	150-212
S2	BM+1% CF	1%	3.5	150-212
S3	BM+1.5% CF	1.5%	5.25	150-212
S4	BM+2% CF	2%	7	150-212

API diagnostics test such as mud balance test, mud rheology test, filtration test, pH analysis are conducted

3.1 Mixing Procedure

For preparing the mud mixing is an important process. The fresh water, sodium hydroxide, bentonite, xanthan gum, and barite combination is blended with a Mixer-Hamilton Beach Mixer. Firstly NaOH is mixed with water at a low speed. This process is continued for 2 minutes. Added bentonite in the blender and stir it for 5 minutes at medium speed. Then mix xanthan gum and stir the blender for 2 minutes. Finally, add barite and stir for 5 minutes to prepare the base fluid. In case of additives mixing, additives are mixed before barite mixing. This Hamilton beach commercial blender is used in laboratory for mixing procedure.

3.3 Mud Rheology test

Rheology is the study of the deformation and flow characteristics of all matter. Fluid rheological metrics such as viscosity, gel strength, and so on can be used to forecast how a fluid would behave under given conditions.

Plastic viscosity-

$$\mu_p = \theta_{600} - \theta_{300} \text{ (cp)} \dots\dots\dots (1)$$

The yield point is the resistance to the initial flow of fluid.

$$\tau_y = \theta_{300} - \mu_p \text{ (lb/100ft}^2\text{)} \dots\dots\dots (2)$$

To begin this test, fill the sample cup up to the scribed line with drilling fluid. Place the cup on the platform of the viscometer. Move the platform up until the fluid level reaches the fill line, making sure the fluid enters both holes on the sleeve. Then tighten the platform's lock nut. Now, mix the sample for 10 seconds on the "STIR" preset. Set the speed using the control knob to 600, 300, 200, and 100, then take the reading when the dial is stable. Now, for 10 seconds, agitate the sample. Set the speed to "GEL" and then turn off the electricity. Wait 10 seconds before turning on the power while glancing at the dial. Take a measurement of the maximum dial deflection before the gel breaks. This reading will be used to calculate the gel strength after 10 seconds. Re-stir the solution and wait 10 minutes before reading the maximum dial deflection for 10 minute gel strength.

3.4 Filtration Test

The OFITE low pressure filter press aids in the determination of drilling fluid filtration and wall cake-building abilities. The filter press design includes a mud sample cell body, a pressure inlet, and a base cap with screen and filter paper. Before starting a test, make sure that every element of the cell is clean and dry, especially the screen. To begin assembling the test cell, turn the base cap upside down and insert a rubber gasket inside. The screen, one sheet of filter paper, and another gasket are then placed. Finally, insert the cell body into the base cap and turn it to secure it. Fill the cell with the freshly stirred sample fluid, leaving 0.5 inch at the top unfilled. Insert a rubber gasket into the top cap. Check that it is seated all the way around the cap. Then, snap the top cap onto the cell body and secure it to the frame. Tighten the T-screw to secure the cell. Under the filter tube, place a clean and dry graduated cylinder. Connect the appropriate pressure source to the top cap's inlet valve and provide 100 psi in 30 seconds or less. The test period begins when the pressure is first applied.

After 30 minutes, measure the volume of filtrate collected and turns off the pressure source's air flow. Record the volume of filtrate collected in ml and level the value "API filtrate". Remove the cell from the frame and disassemble it once all of the pressure has been released from it. Save the filter paper and cake with care. With a moderate stream of water, wash away the extra filter cake.

Using a digital Vernier scale I measure and record the thickness of the filter cake. Five filtration tests are performed here, one for base mud and the other four for varying additive concentrations.



Fig.3 Equipment used in laboratory test

Fig.3 shows the equipments used during laboratory test. These are blender,filtration machine, viscometer, mud balance, digital vernier scale, weighing machine respectively.

5.Calculation

Table 3 Rotation Speed data from rheology test

Rotation Speed	Base mud	S 1	S2	S3	S 4
600	51.5	25	21	20	20
300	41.5	20	15	14.5	14
200	36	17.5	13	12.5	12
100	30	14.5	10	9	8.5

Table 4 Gel strength data from rheology test

Time	Base mud	S 1	S 2	S 3	S 4
10 sec	18	11	8	6	4
10 min	25	20	15	13	10

Table 5 Rheological data analysis result

Properties	Base mud	S 1	S 2	S 3	S 4
μ_p	10	5	6	5.5	6
τ_y	31.5	15	9	9	8
Gel strength at 10 s	18	11	8	6	4
Gel strength at 10m	25	20	15	13	10
Thixotropy	7	9	7	7	6

Table 6 Filtration test dataset

time, min	$\sqrt{t}$	Base mud	S 1	S 2	S 3	S 4
1	1	5	4	3.2	2.9	2.6
5	2.236	9.5	8	7	6.3	5.5
7.5	2.739	11.5	9.9	8.5	7.7	6.8
10	3.162	13	11.5	9.8	9	7.9
15	3.873	16	14	12	10.8	9.5
20	4.472	18	16	13.5	12.5	11
25	5	20	17.5	15	14	12.3
30	5.477	23	19	16.5	15	13.5

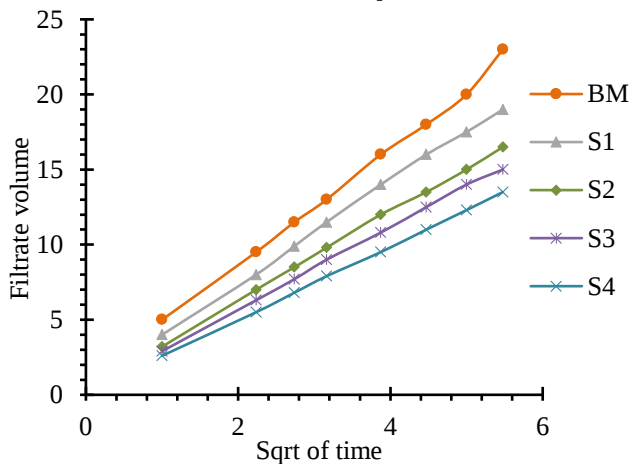
Table 7 Filtration data analysis & spurt loss calculation

Properties	BM	S 1	S 2	S 3	S 4
Mud thickness,mm	2.2	1.71	1.45	1.32	1.15
Spurt loss ,ml	1.1128	0.6264	0.3703	0.2272	0.1275
API filtrate loss,ml (from lab test)	23	19	16.5	15	13.5
API filtrate loss,ml (from equation)	21.89	19.66	16.62	15.17	13.47

6. Discussion

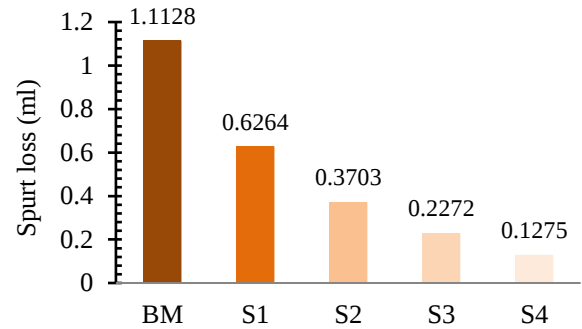
From standard API filtration test data, volume versus square root of time graph are generated for base mud, Sample 1, Sample 2, Sample 3 and Sample 4 muds. Amount of filtrate volume are measured at 1,5,10,20,25,30 minutes and following graphs are generated.

Filtrate volume vs. Square root of time

**Fig.4** Filtrate volume versus square root of time graph of all drilling fluid samples

The graph illustrates that as the concentration of coconut fiber increases, filtering loss decreases. The most filtration loss occurs in base mud. The graph illustrates the least amount of filtration loss while mixing 2% concentration of coconut fiber with base mud.

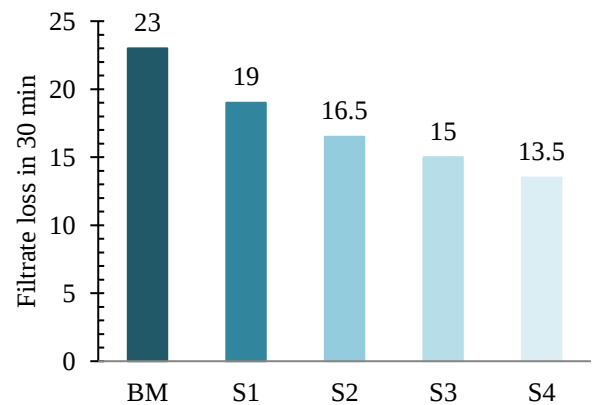
6.1 Spurt Loss Analysis

**Fig.5** Effect of various concentration of coconut fiber on the spurt loss

In fig.5 base mud shows spurt loss of 1.1128 ml filtrate. When sample 1 (BM+0.5% CF) shows spurt loss of 0.6264 ml filtrate. Spurt loss is lowering with increasing amount of coconut fiber concentration. Sample 4 (BM+2% CF) exhibit the highest amount of spurt loss control properties. It means that when sample 4 is used as a drilling mud, 0.1275 ml of mud filtrate will invade formation before mud cake is formed.

6.2 Standard API Filtrate Loss

Coconut fiber's fibrous structure allows it to have a bridging action within the creation of pore throats. This bridging effect helps to limit the migration of particles and filter cake solids into the formation. Coconut fiber limits the flow of liquid and solid particles, consequently lowering the amount of API filtrate by successfully bridging the pore gaps

**Fig.6** Effect of various concentration of coconut fiber on the API filtrate loss of base mud (ml)

This Fig.6 is about total API filtrate loss in 30 minutes. Total API filtrate loss is reducing with increasing amount of coconut fiber concentration. It indicates total fluid loss is reducing. Base mud filtrate loss is about 23 ml. This value is going down to 13.5 ml filtrate loss after mixing 2% of coconut fiber.

6.3 Mud Cake Thickness

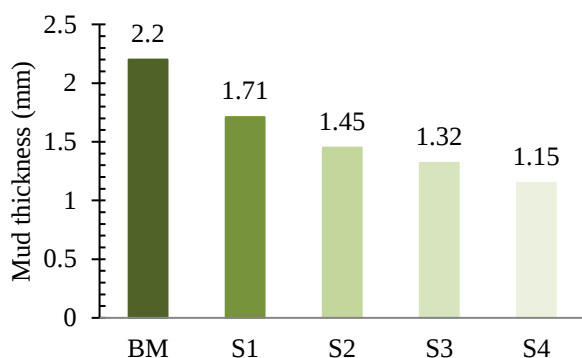


Fig. 7 Effect of coconut fiber on the mud thickness (mm)

By analyzing this fig.7 chart we have noticed that mud thickness is reducing gradually after mixing varying concentration of coconut fiber. The lowest mud thickness we get at sample 4 (BM+2% CF). Low mud thickness is considered as good drilling fluid characteristics. When the mud cake formed during drilling becomes excessively thick, it can lead to several problems that can impact drilling operations. Fluid loss is increased with thick mud cake formation. The frictional drag between the drill string and the wellbore can be increased by a thick mud layer. Furthermore, the thick cake might function as an adhesive, leading the drill string to become entangled in the wellbore. Another goal of this project was to reduce mud thickness. The mud cake's 2.2mm thickness is decreased to 1.15mm. Fine particles or fibers produce thinner cakes as compared to larger particles. This means that coconut fiber has the ability to reduce fluid loss while simultaneously providing a thin impermeable mud cake, making it a viable fluid loss control agent.



Fig.8 Mud cake formed by base fluid, sample 1, sample 2, sample 3, sample 4 respectively

Fig.8 represents all the mud cakes create after filtration test. It shows reduction in mud thickness after mixing coconut fiber in base mud.

6.4 Rheological properties analysis

The rheological characteristics of drilling fluid can be affected by the addition of coconut fiber. Rheology is the study of how fluids flow and change shape when forces are applied. Plastic viscosity represents the frictional forces between solid particles, solids and liquids particles, and liquids particles itself (Al-hameedi,2019). The effect of coconut fiber on the plastic viscosity of drilling fluid might vary based on elements including the fiber's content, length, and the drilling fluid's composition. As we use small size

particle of coconut fiber on drilling fluid it create a decreasing impact on plastic viscosity. In fig.9 the first column of every segment represents the plastic viscosity. Plastic viscosity's values of each sample are less than standard API values. Adding increasing amount of bentonite, which is work as viscosifier agent, can increase plastic viscosity of sample muds. When pumps are turned on (dynamic drilling operations), the fluid intrinsic characteristic known as YP determines the fluid's capacity to lift cuttings, and when the pumps are turned off (static drilling activities), the fluid's ability to suspend cuttings is determined by the gel strength. Difference between initial and final gel strength represent as thixotropy which is the ability of the fluid to develop gel strength with time. Yield point of base mud is 31.5. To drill large size hole this kind of yield value of drilling fluid is used to lift up drill cutting. Considering API standard all samples shows compatible yield point values. However, sample 1 (0.5% of CF) shows more optimistic value of yield point. Too low gel strength cannot hold the drill cutting.

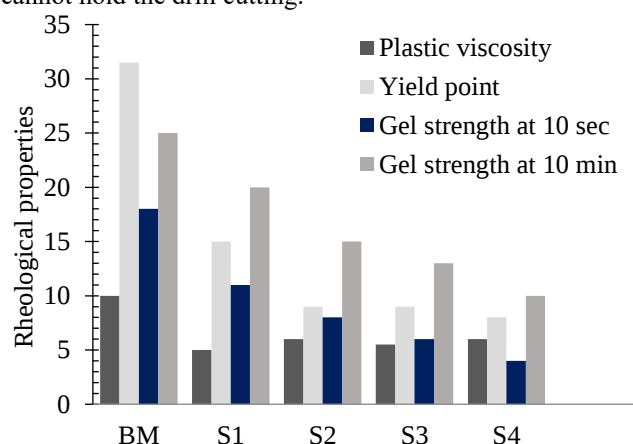


Fig.9 Effect of various concentration of coconut fiber (CF) on the mud rheology

Thus blockage can happened at lower side of drill-hole. On the other hand if gel strength becomes too high, solidification of drill fluid can occur. High pump pressure will required to move the drill cutting upward. On the basis of API standard final gel strength of each mud sample are acceptable. On the basis of initial gel strength sample 4 (2% of CF) is the optimum concentration.

7. Conclusion

This experimental study highlights the potential of coconut fiber as an eco-friendly fluid loss control additive in drilling fluids. Its positive environmental attributes, effective filtration control, and potential cost benefits make it a promising candidate for sustainable drilling practices.

Recalling the objective, it has been observed that coconut fiber exhibits effective fluid loss control properties, aiding in the formation of a thin and impermeable filter cake and reducing fluid loss. Sample 4 (BM+2% CF) shows the best result by reducing filtration loss to 41.31% and reduce mud thickness to 47.72% of base mud.

Coconut fiber shows compatibility with rheological properties of all sample mud. Sample 1 (BM+0.5% CF) exhibited the most optimistic value in yield point but overall sample 4 (BM+2%CF) shows the most optimistic result in all properties.

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NOMENCLATURE

<i>Filtrate volume</i>	: The volume of fluid lost through filtration during a test, ml
μm	: Micrometers
<i>API</i>	: American Petroleum Institute
<i>BM</i>	: Base Mud
<i>CF</i>	: Coconut Fiber
<i>YP</i>	: Yield Point
<i>PV</i>	: Plastic Viscosity
<i>PPP</i>	: Potato Peel Powder
<i>CMC</i>	: Carboxymethyl Cellulose Sodium
<i>PAC</i>	: Polyanionic Cellulose
<i>HEC</i>	: Hydroxyethyl Cellulose
<i>NaOH</i>	: Sodium Hydroxide
<i>Spurt loss</i>	: Initial filtration of liquid before mud cake formation,ml
<i>Mud cake</i>	:Solid layer formed on borehole walls to prevent fluid leakage
<i>Gel strength</i>	:Ability of a drilling fluid to suspend drill cuttings during static conditions
<i>Thixotropy</i>	:The ability of a fluid to develop gel strength over time when undisturbed
<i>Barite</i>	:A weighting agent used in drilling fluids
<i>Bentonite</i>	:A clay additive used to control fluid loss and improve mud properties
<i>Xanthan gum</i>	:A biopolymer used as a viscosifier in drilling fluids