Petroleum and Coal

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An Experimental Study of Effects of Egg Shell and Snail Shell Powder on Rheological and Filtration Properties of Potassium Chloride Polymer Drilling Fluids

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Received April 23, 2019; Accepted July 22, 2020

Abstract

In this paper, the effect of two potential drilling fluid bio-additives, egg shell, and snail shell powders, on the rheological and filtration properties of 11ppg potassium chloride (KCl) polymer drilling fluid samples as determined experimentally is analyzed. The control mud sample was formulated with bentonite, caustic soda, xanthan gum, potato starch, potassium chloride, and barite in water. Rheology and filtration experiments were conducted at room temperature for the control mud sample and ten samples in which potato starch was replaced with either egg shell or snail shell powder at different concentrations - 2g, 5g, 10g, 15g, and 20g. Five additional 11ppg KCl-polymer mud samples, one with the control mud formulation and samples with 2g eggshell, 5g eggshell, 2g snail shell, and 5g snail shell powder respectively, were aged for 16 hours in a roller oven at 250ºF prior to the rheology and filtration experiments.

The results obtained at 120ºF show that 2g and 5g concentration of the bio-additives further decreased the 15cp control sample plastic viscosity by an average of 34%, which was within expected limits, while the yield point, which was 62% above typical values, was decreased with 2g and 5g concentration of egg shell powder by 8% and 15% respectively. A 10% decrease in yield point was observed with 5% snail shell powder concentration. The 10 min. gel strength was decreased to expected typical values for 2g egg shell powder, 5g egg shell powder, and 5g snail shell powder by 7%, 7%, and 11%, respectively. The filtrate loss was minimized by 2g egg shell powder and 5g snail shell powder to 23mL and 24mL from 25mL for the control sample. The addition of 2g egg shell powder resulted in a cake thickness less than 0.1mm. The results show that on aging and at room temperature, eggshell and snail shell powder at 2g and 5g, respectively, can serve as a good substitute for conventional additives in improving the rheological and filtration properties of KCl-polymer drilling fluid. However, only 2g egg shell powder concentration can serve as a substitute in improving the filtration properties of the KCl-polymer mud as it had the best cake quality and least filtrate volume loss.

Keywords: *KCl-polymer drilling fluid; Egg shell powder; Snail shell powder; Rheological and filtration properties.*

1. Introduction

The need for drilling fluid systems, which are both environmentally friendly and effective for drilling through troublesome formations like sloughing shales, has led to several investigations into suitable plant extracts and agricultural wastes that can improve the rheological and filtration properties of water based drilling fluids. Oak seed extract [1] and black myrobalan [2] used at laboratory scale in water based mud as deflocculants, preserved the stability of bentonite in the presence of salts, reducing rheological parameters and fluid loss value. Some of the additives that have been evaluated and reported to be effective for minimizing fluid loss and mud cake thickness include rice husk ash [3], periwinkle shell ash [4], and corn cob cellulose [5].

The potential for using egg shell and snail shell powder as mud weight and pH enhancers for water based drilling mud has been investigated [6] with egg shell powder found more effective in enhancing water based drilling mud weight while snail shell powder more effective in pH enhancement. Both materials were compared because of their high calcium carbonate ($CaCO_3$) content with predominant minerals being aragonite and calcite in eggshell and snail shells respectively. The rheological properties of water-based mud with pure calcium carbonate as a weighting agent were compared to samples prepared with calcium carbonate extracted from egg shells. Though higher amounts of $CaCO_3$ from egg shells were needed to achieve a mud weight of 10.5ppg as compared to mud formulated from pure $CaCO_3$, the rheological properties obtained for both formulations were similar [7].

The effect of calcium carbonate, a commonly used bridging agent on the rheological and filtration properties on water-based drilling fluids on drilling fluid compositions prepared for geothermal reservoirs, was evaluated by the addition of 10ppb calcium carbonate to different polymer suspensions. The formation of impermeable filter cake led to a decrease in filtration fluid loss; however, the calcium carbonate did not improve the rheological properties of the drilling fluid [8]. In a study to investigate the effect of different particle size distributions of calcium carbonate used as the bridging agent on the rheological properties of drill-in fluids made up of water, xanthan, starch, potassium hydroxide, and potassium chloride, it was found that the particle size distribution of the calcium carbonate did not change the rheological properties of the evaluated drill-in fluids. However, the filtration properties of the drill-in fluids depend on the permeability obtained from the permeability plugging tester discs [9].

Rheological and filtration experiments were performed to design a drilling fluid system for a stratum with carbonaceous slate. The requirement was to minimize fluid loss and enhance mud salinity. The results showed that for a potassium-based polymer, treatment with 1.5% calcium carbonate is an inexpensive but effective option for achieving good plugging effect and improved mud cake quality [10]. The aim of this paper is to experimentally investigate the effect of egg shell and snail shells on the rheological and filtration properties of 11.0 ppg KCl-polymer water-based mud.

2. Experimental section

2.1. Materials and instruments

The effect of egg shell powder and snail shell powder on the rheological and filtration properties of KCl-polymer water-based drilling mud was independently investigated. The control mud sample composition is shown in Table 1, while compositions for the samples treated with egg shell powder and snail shell powder are shown in Table 2 and Table 3, respectively. All drilling fluid samples were prepared on the basis of a pilot test volume of 350 mL, which is equivalent to one barrel of the actual system volume. The instruments used for the experiments include mud balance, pH meter, roller oven, aging cells, direct-indicating viscometer (Fann Model 35 6-Speed Viscometer), and standard filter press (low-temperature/low-pressure filtration apparatus).

Table 1. Control mud sample composition (11ppg)

Constituents	Concentration	Function
De-ionized water	304 mL	Base fluid
API bentonite	7 grams	Viscosifier
Caustic potash	0.25 grams	Alkalinity Control
Xanthan gum	1 gram	Viscosifier
Potato starch	4 grams	Filtration Control
Potassium chloride (KCl)	20 grams	Inhibition Source of K^+ion
Barite	126 grams	Weighting agent

Table 2. Composition of Egg Shell Powder treated Mud Samples (11ppg)

Constituents	A	B	C	D	E
Water (mL)	305	303	299	295	291
API bentonite (g)	7	7	7	7	7
Caustic potash (g)	0.25	0.25	0.25	0.25	0.25
KCl (g)	20	20	20	20	20
Egg shell (g)	2	5	10	15	20
Barite (g)	128	127	126	125	124

Table 3. Composition of Snail Shell Powder treated Mud Samples (11ppg)

Constituents	F	G	H	I	J
Water (mL)	304	301	294	288	282
API bentonite (g)	7	7	7	7	7
Caustic potash (g)	0.25	0.25	0.25	0.25	0.25
KCl (g)	20	20	20	20	20
Egg shell (g)	2	5	10	15	20
Barite (g)	129	130	131	132	133

2.2. Methods

2.2.1. Preparation of egg shell (ES) and snail shell (SS) powders

Egg shells and snail shells were first extracted from boiled eggs and de-shelled snails, respectively. The extracted shells were crushed into smaller sizes; this ensured a large surface area for effective drying and ease of grinding. The broken shells were sun-dried for 3-5 days to remove water content. The dried samples were ground, using a manual grinder, and then stored in a clean petri-dish.

The ground samples were sieved using a sieve shaker, and particles retained on the 75μm mesh size (i.e., particle sizes between 150μm and 75μm) were stored for experimental use (for both ground samples). The specific gravity of the egg shell powder and snail shell powder for this particle size distribution was 1.17 and 0.84, respectively.

2.3. Procedure

The control mud sample was formulated with xanthan gum as a viscosifier to supplement the pre-hydrated bentonite and potato starch to provide filtration control in KCl-polymer drilling fluid. The recipes for all samples tested (the control samples and those with the bio-additives) were formulated to obtain a mud weight of 11ppg. The viscosity at varying shear rates (600rpm, 300rpm, 200rpm, 100rpm, and 6rpm) was measured using a six-speed direct-indicating viscometer. Gel strength readings were taken at the 3-rpm speed after allowing the sample to stand undisturbed for 10 seconds and then after 10 minutes. Filtration properties were obtained using a Standard filter press. The filtrate volume collected was measured using a measuring cylinder in milliliters over 30 minutes, while the thickness of the mud cake was measured to the nearest millimeter. The rheological and filtration experiments were conducted for ten samples (A-J) according to API specifications [11]. Five samples of 11ppg KCl-polymer drilling fluid had egg shell powder in weight proportions ranging from 2g to 20g (samples A-E) while five additional samples (samples F-J) had snail shell powder in similar weight proportions of 11ppg KCl-polymer drilling fluid (2g, 5g, 10g, 15g, and 20g). These bio-additives were used in place of the potato starch. Five samples, the control mud, a sample with 2g egg shell powder, 2g snail shell powder, 5g egg shell powder, and a sample containing 5g snail shell powder, were aged for 16 hours and at a temperature of 250°F in a roller oven. Rheology and filtration experiments were then conducted on the aged samples. Plastic viscosity (PV) was obtained from the difference in the viscometer dial readings at 600 and 300 rpm while the yield point (YP) was obtained by subtracting the PV value from the 300-rpm reading. The pH range for the samples was 8.8–10.5, with the pH increasing with increasing bio-additive concentration.

The performance of the mud samples was benchmarked against typical rheological and filtration properties for KCl-polymer mud with mud weight of 10 to 11 ppg at 120°F, which includes a plastic viscosity range of 15 to 25 cp, yield point between 7 and 15 lb/100 ft^2, 10 sec. The gel strength of 2 to 8 cp, 10 min. The gel strength of 8 to 15 cp, and API filtrate of 5 to 8 mL/30 min.

3. Results and discussion

3.1. The effect of varying additive concentration on mud rheology

The measured PV and YP values for the control sample at ambient conditions are 19 cp and 39 lb/100 $ft^{2,}$ respectively. While the PV value was within the expected range, the YP value obtained was much higher than typical values. The general trend observed with the addition of either egg shell powder or snail shell powder, as shown in Figure 1, is the decrease in both PV and YP for 2g and 5g concentration. For the samples with 10g of the bio-additives, PV and YP values are close to control sample measured values. A decrease in PV values with a corresponding increase in YP was observed for samples with 15g and 20g concentration of the bio-additives. At 20g concentration, the PV values are below the expected minimum values (53% and 68% below the control PV value for egg shell powder and snail shell powder, respectively) while the YP values exceeded the control sample values by 46% and 51% for egg shell powder and snail shell powder respectively. This is indicative of high concentrations of colloidal solids. The PV values for 10g concentration were within the expected range, but the YP values were not. The optimal concentrations of bio-additives in terms of PV and YP are 2g of egg shell powder and 5g of snail shell powder.

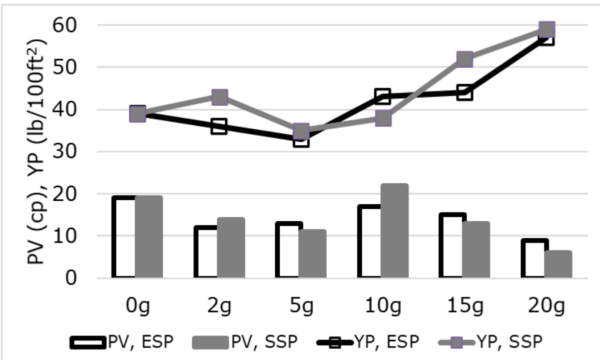

Figure 1. Effect of egg shell and snail shell powder on plastic viscosity and yield point at ambient conditions

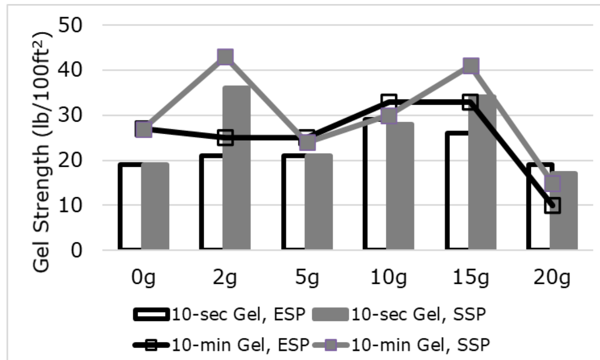

Figure 2. Effect of egg shell and snail shell powder on gel strength (10sec and 10min) at ambient conditions

The gel strength measured at 10 seconds and 10 minutes for the control fluid both exceeded the typical, expected values (19 and 27 lb/100 ft^2 as compared to 8 and 15 lb/100 ft^2). Increasing concentrations of egg shell powder by 2g, 5g, 10g, and 15g in the KCl-polymer mud resulted in an increase in the 10 sec. gel strength by 11%, 11%, 53%, and 37%, respectively, compared to the control sample value. A similar trend was observed for snail shell powder except for an 89% in the 10 sec. gel strength for the sample with 2g concentration, as shown in Figure 2. The bio-additives dropped the 10 min. gel strength values for 2g and 5g egg shell powder and 5g snail shell powder by 7%, 7%, and 11%, respectively. As observed for the 10 sec. gel strength, at concentrations of 10g and 15g the 10 min. gel strength is increased further. It can be inferred that at 2g and 5g concentration, the bio-additives have a deflocculating effect on the KCl-polymer drilling fluid, while above 10g, the high colloidal content increases the gel strength. At 20g concentration of the bio-additives, the gel strength values were observed to unexpectedly decline below the measured values for the control samples at ambient conditions.

3.2. The effect of bio-additive concentration on filtration properties

For a mud formulated at 11ppg, a filtrate volume range of 5–8 mL/30min is typical. All samples tested, the control sample inclusive, had filtrate volume loss in excess of the typical values, as shown in Figure 3. The filtration properties of the KCl-polymer drilling fluid were improved by 2g of egg shell powder and 5g of snail shell powder with 8% and 4% reduction in filtrate loss, respectively. As expected, the general trend observed for bio-additive concentration of 10g and above is increasing filtrate loss with filtrate loss volume in excess of 160mL observed for 20g concentration.

A linear relationship between the bio-additive concentration (2-15 g) and mud cake thickness for 2g to 15g exists for both egg shell powder and snail shell powder. The mud cake thickness increased by about 1000% over the control mud value of 0.1mm for the 20g concentration of the bio-additives. The sample with 2g egg shell powder concentration produced the best cake quality.

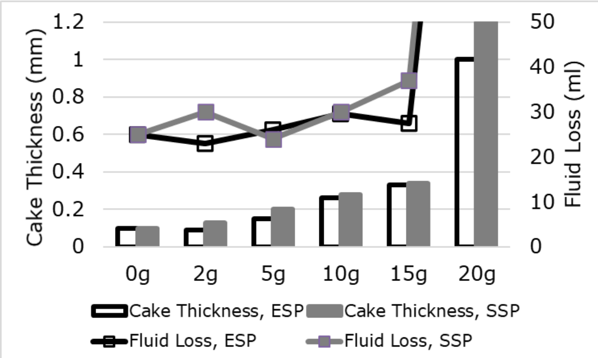

Figure 3. Effect of egg shell and snail shell powder on fluid loss and filter cake thickness at ambient conditions

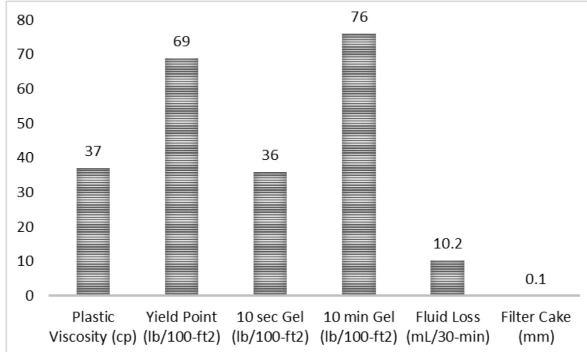

Figure 4. Rheological and Filtration properties for the aged control sample

3.3. The effect of bio-additives on aged samples

Following the rheological and filtration experiments carried out at ambient conditions, two concentrations (2g and 5g) were investigated further. The rheological and filtration properties for aged samples based on the control mud recipe, 2g bio-additive concentration, and 5g bio-additive concentration are presented in Figure 4, Figure 5, and Figure 6, respectively.

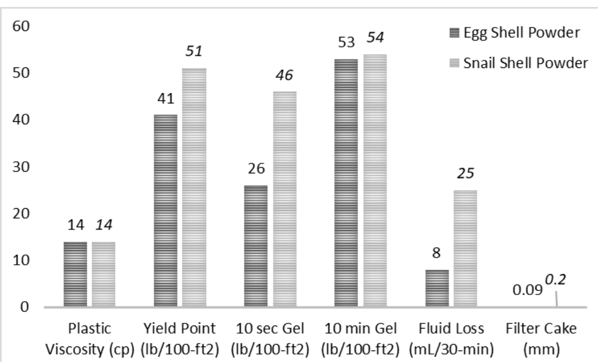

Figure 5. Rheological and Filtration properties for 2g bio-additive concentration (aged samples)

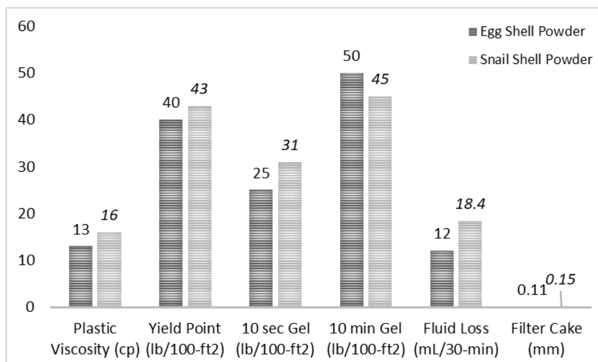

Figure 6. Rheological and Filtration properties for 5g bio-additive concentration (aged samples)

The plastic viscosity and yield point of the 11ppg KCl-polymer mud were improved by the bio-additives at 2g and 5g concentration for both egg shell powder and snail shell powder with similar PV and YP values. An average reduction of 61% and 37% in PV and YP was observed for the aged samples.

The 10-sec. gel strength was reduced by 28% and 31% for 2g and 5g egg shell powder concentration compared to the control sample value. It is worth noting that a 100% increase in gel strength was observed in the aged samples over the samples evaluated at ambient conditions. For the samples with snail shell powder, the 10-sec. gel strength increased by 28% for 2g concentration but reduced 14% for 5g concentration. The 10-min. the gel strength of the 11ppg KCl-polymer mud was improved by the bio-additives at 2g and 5g concentration for both egg shell powder and snail shell powder with an average reduction of 34% observed for the aged samples.

The filtration properties of the KCl-polymer mud aged were not improved by 5g egg shell powder, 2g snail shell powder, or 5g snail shell powder concentration. Higher filtrate loss and filter cake poorer in quality were observed for these bio-additive concentrations. The exception is the 2g egg shell powder concentration with 8 mL/30 min. filtrate loss and < 1 mm cake thickness. Treatment of the 11ppg KCl-polymer mud with 2g egg shell powder concentration resulted in 22% and 10% reduction in filtrate loss and filter cake thickness, respectively.

4. Conclusions

Egg shell powder at low concentrations, 2g in this study, is effective in improving both the rheological and filtration properties of KCl-polymer water-based drilling mud. Snail shell powder at 5g concentration has a higher potential of enhancing drilling fluid rheology as compared to its filtration properties. Egg shell powder and snail shell powder at low concentrations have a deflocculating effect on KCl-Polymer mud. At concentrations above 10g, the bio-additives have a reverse flocculating effect on the drilling fluid. Egg shell powder at low concentrations, 2g in this study, has the potential to both supplement pre-hydrated bentonite and provide filtration control for KCl-polymer water-based drilling mud.

Recommendation

Based on these results and conclusions of the experimental research study, the following recommendations are suggested for future work:

- The effect of egg shell powder on the rheology and filtration properties of different water-based mud formulations below 2g concentration should be investigated at HTHP conditions.
- The effect of egg shell powder on KCl-polymer mud in the presence of starch should be investigated.

Acknowledgments

The authors would like to thank Prof. O.D. Orodu, the Head of the Department of Petroleum Engineering, Covenant University, Ota, Ogun State, Nigeria.

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