Effectiveness of Cellulose From Waste Paper Material as Water-Based Mud Viscosifier on Rheological Properties of Oil and Gas Drilling Fluids

By

Oluwatoyin O. Akinsete[1]* and Daniel G. Adeyinka*

ABSTRACT

Drilling mud are complex heterogeneous fluids consisting of several additives. Cellulose from waste paper are viscosity builder in polymers, its use as viscosifier additive will reduce overall well cost, improve waste management while reducing environmental pollution. This study experimentally examined the effectiveness of waste paper cellulose as a viscosifier. Rheological properties such as density, pH and rheology (plastic viscosity, yield point) tests were performed and compared to a control mud. The mud samples were beneficiated to meet API specification for drilling fluids. At temperatures 28, 45 and 60 ˚C, the sample and control muds had the same density of 8.7 lb/gal; the pH values were 7.5 and 7.7, respectively. They have the same average plastic viscosity of 4.3 (±0.3) cp; while the average yield point values were 17.0(±0.3) and 12.0(±0.4) lb/100sqft, respectively. After the mud samples were beneficiated, results showed that, the sample mud with density of 8.8 lb/gal, pH of 9.0±0.4, average plastic viscosity of 12 cp and yield point of 37 lb/100sqft compared with control mud density of 8.7 lb/gal, pH of 9.3±0.3, average plastic viscosity of 11 cp and yield point of 40 lb/100sqft. Results showed that cellulose extracted from waste paper can replace standard viscosifiers.

Key words: Additives; Cellulose; Drilling fluid; Rheological properties; Viscosifier; Waste paper

INTRODUCTION

Drilling fluid (mud) in its basic form is a mixture of fluid (water or oil), clay and some sort of viscosifying agent. It is any fluid which is circulated through a well in order to remove cuttings from a wellbore.The traditional use of the drilling fluids, since the early twentieth century, was to remove cuttings continuously, other uses according to Darley and Gray[2] and Growcock and Harvey[3] are transport rock cuttings to surface through annulus; suspend cuttings in fluid if circulation is stopped; cool and clean the bit; manage formation pressure to maintain well-bore stability; seal the formation pores by forming low-permeability filter cake to prevent inflow of formation fluids into the well; provision of necessary hydraulic power to down-hole equipment; minimize reservoir damage; aid in collection and interpretation of data available through drill cuttings, cores, and electrical logs etc.

As the drilling fluids evolved and in order to enhance their usage, their design was changed or modified by the introduction of various additives for the drilling process[4,5]. Additives commonly used in drilling muds are broadly classified reactive and inert, are added to drilling fluids to perform specialized functions such as: Alkalinity and pH Control, designed to

---

[1] Corresponding author: Email: kunle2223@yahoo.com

* Authors' Address: Department of Petroleum Engineering, University of Ibadan, Ibadan, Nigeria.

[2] Darley, H.C. and Gray, G.R. 1988. Composition and Properties of Drilling and Completion Fluids. Gulf Professional Pub.

[3] Growcock, F. and Harvey, T. 2005. Drilling Fluids. In ASME Shale Shaker Committe, *Drilling Fluids* Processing Handbook. Elsevier.

[4] Moore, P.L. 1974. Drilling Practice Manual. PennWell Pub. Co.

[5] Nwaoboli A. 2014. Investigation of additives on drilling mud performance with tønder geothermal drilling as a case study". Master Thesis, Chemical Engineering Department, Aalborg University Esbjerg

control the degree of acidity or alkalinity of the drilling fluid e.g. limes, caustic soda and bicarbonate of soda. Also, Defoamers, are used to reduce the foaming action in salt and saturated saltwater mud systems, by reducing the surface tension. While Emulsifiers (e.g. fatty acids and amine derivatives) are added to a mud system to create a homogeneous mixture of two liquids (oil and water). Also, Filtrate Reducers, such as bentonite clays, CMC and pre-gelatinized starch, are used to reduce the amount of water lost to the formations and Lost Circulation Materials are inert solids used to plug large openings in the formations to prevent the loss of whole drilling fluid[6,7].

There are also, viscosity control additives categorized as: viscosifiers (viscosity enhancers) and viscosity reducers. Clays are natural absorbent, their ability to swell and gel, make them perfect viscosity enhancers. Bentonite (clay) is the most commonly used additive for increasing viscosity of the drilling fluid. Bentonite when exposed to water attracts water to its negative face. This unique characteristic allows bentonite to adsorb 7 to 10 times its own weight in water and swelling up to 18 times its dry volume. *Wyoming Bentonite* is the most common form of viscosity enhancer used commercially. It is composed essentially of montmorillonite clay, also known as hydrous silicate of alumina[8]. Several other viscosifiers commonly used are CMC, PAC-R, starch and the common factor among all is that they all contain cellulose responsible for viscosity building.

Cellulose, hemi-cellulos and lignin can be found in paper, study has shown that paper is composed of 70% cellulose (paperonweb.com/composition of paper). This present work therefore investigated the development of a cost-effective local additive material such as waste paper as substitute for foreign additives. Waste paper primarily contains cellulose responsible for viscosity building in polymers[9], its use as viscosifier additive will reduce overall well cost, improve waste management while reducing environmental pollution.

Drilling fluid consist of base liquid (fresh or saline water, diesel or crude and Mineral Oil or other synthetic fluids), dispersed solids (Colloidal particles, which are suspended particles of various sizes) and dissolved solids (these are salts). Water based muds (WBM) consist of water/brine as the base fluid, they are environment friendly, the drill cuttings can be disposed of easily. A conventional WBM uses a polymer as a viscosifying agent. Oil based drilling muds (OBM) have oil (such as diesel, mineral or synthetics) as the base fluid. There are two types of OBM systems: (1) invert emulsion, where water is the dispersed phase and oil the continuous phase (water-in-oil mud), and (2) emulsion muds, where oil is the dispersed phase and water is the continuous phase (oil-in-water mud). Emulsifiers are added to control the rheological properties (water increases viscosity, oil decreases viscosity). All solids in OBM are considered inactive as they do not react with oil, they are highly temperature-stable fluids with excellent fluid loss control and good cutting carrying ability. Their drawbacks are possible environmental hazards, like discharge into aquifers and causing pollution. Based on viscosity, drilling fluids are classified into two major types: Newtonian and Non-Newtonia fluids[10,11]. The dissolved solids in drilling fluid are classified as active and inactive solids. The *active* solids (clays, polymers etc) are viscosity enhancers, while the inactive solids

[6] Baker Hughes INTEQ 1995. Drilling Engineering Workbook. A Distributed Learning Course. 80270H Rev. B. Houston, Texas.

7 Subhash, N.S., Narayen, H.S. and Chineye, C.O. 2010. Future Challenges of Drilling Fluids and their Rheological Measurements. American Association of Drilling Engineers (AADE) Fluids Conference and Exhibition, Houston, Texas, April 6-7.

8 Dyke, K.V. 2000. Drilling Fluids: Rotary Drilling Series (Unit II). Austin, TX: The University of Texas.

9 Dagde, K. K. and Nmegbu, C. G. J. 2014. Drilling fluid formulation using cellulose generated from groundnut husk. International Journal of Advancement in Research & Technology, vol. 3, pg 65-71.

10 Bingham, C.E. 1922 Fluidity and Plasticity. New York: McGraw-Hill.

11 Clark, E.P. 1995. Drilling Mud Rheology and the API recommended Measurements. Society of Petroleum Engineers, Inc.

(Barite and Hematite) are those that do not react with the water and chemical, they are added to drilling fluids as weighing agents[12,13,14].

Most of the drilling fluid functions are controlled by its rheological properties. Rheology is the study of the deformation of fluids and flow of matter. Rheological properties are basis for all analysis of well bore hydraulics and to assess the functionality of the mud system[7,15]. Rheological properties of drilling mud include yield point, density, gel strength and viscosity, they are tested throughout the drilling operations. It is critical to control and maintain rheological properties as failure to do so can result in financial and loss of time, and in extreme cases, it could result in the abandonment of the well[2]. According to Skalle[16], rheology measurements are influenced by 2-speed rotational viscometer, but has petroleum industry has evolved in all aspect, the need for higher quality rheology control has arisen with the development of 6-speed and 8-speed rotational viscometer. Also, in his book, Skalle gave three different approaches of determining rheology constants: 2 data points oil field approach, 2 data points standard approach and 6 data points regression approach. In this study, 8-speed viscometer and the Bingham 2 data points oil field method was used (equs. 1 and 2).

$$\mu_p = \theta_{600} - \theta_{300} \quad 1$$

Where θ_{600}, θ_{300} are the viscometer dial readings at N= 600 rpm and N= 300 rpm, respectively.

$$\tau_Y = \theta_{300} - \mu_p \quad 2$$

Besides rheological test, other tests such as filtration tests, pH, chemical analysis and resistivity are conducted throughout drilling process. Drilling muds are always treated to be alkaline (i.e., a pH > 7). The pH will affect viscosity, bentonite is least affected if the pH is in the range of 7 to 9.5. Above this, the viscosity will increase and may give viscosities that are out of proportion for good drilling properties[6]. pH is commonly measured with pHydrion paper. An electronic pH meter was used in this study.

This work experimentally examined the efficacy and usefulness of waste paper cellulose as a viscosifier. Rheological properties such as density, pH and rheology (plastic viscosity, yield point) tests were performed and compared to a control mud. The mud samples were beneficiated to meet API specification for drilling fluids.

MATERIALS

The equipments used for this study include:

Mud balance (Fann Model 140), pH meter (Model 8000), A five spindle Hamilton Beach Commercial Multimixer (Model 9B), Digital weighing balance (Mettler PB 3002-S), Rheometer (Model 800), Fann Visometer (Model 35A), Stopwatch, sieving mesh, bucket and bowl.

The reagents used are as follows: water, waster paper, cellulose, Bentonite, Barite, CMC and KOH.

METHODOLOGY

[12] Bourgoyne Jr., A.T., Millheim, K.K., Chenevert, M.E. and Young Jr. F. 1986. Applied Drilling Engineering. Richardson, TX: Society of Petroleum Engineering.

[13] Azar, J. and Samuel, G.R. 2007. Drilling Engineering. PennWell Corporation.

[14] Annudeep, S.D. 2012. Rheological Properties and Corrosion Charateristics of Drilling Mud Additives. M.Sc. Dissertation, Dalhousie University, Halifax, Nova, Scotia.

[15] Olatunde A.O., Usman M.A., Olafadehan O.A., Adeosun T.A. and Ufot O.E. 2011. Improvement of Rheological Properties of Drilling Fluid using Locally Based Materials, Petroleum & Coal ISSN 1337-7027

[16] Skalle P. 2011. Drilling Fluid Engineering, Chemical Review. 2nd Edition. Pal Skalle & Ventus Publishing Aps. ISBN 798-87-7681-929-3

The study was performed in University of Ibadan, Ibadan, Nigeria located on latitude 7.439824 and longitude 3.893016 in Southwest Africa. Waste paper (0.07kg) was sourced and sorted from University of Ibadan, Ibadan.

The waste paper was grouped into sample A (soaked, blended and sieved liquid paper) and sample B (soaked and sieved liquid paper).

Cellulose Extraction

Cellulose extraction was achieved by soaking waste paper reduced to smaller sizes in distilled water for seven days (a week). This was later blended and sieved to store liquid cellulose.

Mud Sample Preparation.

Mud formulation was performed by measuring 10, 15, 150 and 200 ml of prepared liquid phase (Table 1) into a multimixer and 21g of bentonite added in small amounts while mixing for a total period of 15 mins until complete homogeneity was achieved. The samples (9) were stored in a container for 24 hours prior to conducting any test.

Mud Density Test

The mud density test was conducted using Mud balance (Fann Model 140). Briefly, each sample was poured into the multimixer cup and mixed. After mixing, the sample was poured to fill the mud balance cup and covered. The mud balance cup was degassed and spill-overs on the mud cup were cleaned. The mud cup was then balanced on the fulcrum and the reading (lb/gal) at the point where the rider balances on the balance arm was taken. The reading was taken to the nearest 0.1 lb/gal (Tables 1 and 2)

Table 1: Varying concentration of drilling fluid prepared

	Volume of sample (ml)	Volume of water (ml)	Total volume of liquid phase (ml)
Mud sample A	10	350	360
	15	350	365
	150	200	350
	200	150	350
Mud sample B	10	350	360
	15	350	365
	150	200	350
	200	150	350

Table 2: Relogical Properties of control Mud

Testing days	300 rpm	600 rpm	Plastic Viscosity (cp)	Yield Point (lbs/100 sqft)	Density (lb/gal)
DAY 1	11	15	4	7	8.7
DAY 2	11	16	5	6	8.7
DAY 3	13	18	5	8	8.7
DAY 4	15	21	6	9	8.7
DAY 5	15	21	6	9	8.7

Rheology Test

The rheology test was performed by pouring each sample into the multimixer cup and mixed. The agitated sample was then poured into the viscometer cup and placed in the viscometer. The viscometer was turned on and the shear stress of each sample was recorded at 600rpm and 300rpm (Tables 1-5). After the reading was taken, the control knob on the rheometer and the power switch was then turned off.

Table 3: Relogical Properties of Samples A and B

Testing Days	300 rpm		600 rpm		Plastic Viscosity, μ_p		Yield Point, τ_y		Density (lb/gal)	
	A	B	A	B	A	B	A	B	A	B
Day 1	10(±1)	11(±1)	14(±1)	14(±1)	4(±1)	4(±1)	6(±1)	6(±2)	8.7	8.7
Day 2	12(±2)	11(±1)	17(±2)	16(±1)	5(±1)	5(±1)	7(±2)	6(±1)	8.7	8.7
Day 3	14(±2)	14(±2)	19(±1)	19(±1)	5(±1)	5.5(±1)	9(±3)	8(±2)	8.7	8.7
Day 4	15(±1)	15(±1)	21(±1)	21(±1)	5(±1)	5(±1)	10(±1)	10(±1)	8.7	8.7
Day 5	15(±1)	15(±1)	21(±1)	21(±1)	5(±1)	5(±1)	10(±1)	10(±1)	8.7	8.7

Table 4: Rheological Properties of control mud with increasing temperture

Testing Days	28˚C		45˚C		60˚C	
	300 rpm	600 rpm	300 rpm	600 rpm	300 rpm	600 rpm
Day 1	10	13	12	15	18	21
Day 2	22	29	19	23	23	26
Day 3	25	32	23	27	24	26
Day 4	26	33	24	29	24	27
Day 5	27	34	25	30	25	29
	PV, μ_p	YP, τ_y	PV, μ_p	YP, τ_y	PV, μ_p	YP, τ_y
Day 1	3	7	3	9	3	15
Day 2	7	15	4	15	3	20
Day 3	7	18	4	19	2	22
Day 4	7	19	5	19	3	21
Day 5	7	20	5	20	4	21

Table 5: Rheological Properties of mud sample A with increasing temperture

Testing Days	28˚C		45˚C		60˚C	
	300 rpm	600 rpm	300 rpm	600 rpm	300 rpm	600 rpm
Day 1	13	18	12	16	14	17
Day 2	17	24	16	20	15	18
Day 3	19	24	16	20	20	25
Day 4	20	28	16	19	19	23
Day 5	22	29	17	20	20	24
	PV, μ_p	YP, τ_y	PV, μ_p	YP, τ_y	PV, μ_p	YP, τ_y
Day 1	5	8	4	8	3	11
Day 2	7	10	4	12	3	12
Day 3	5	14	4	12	5	15
Day 4	8	12	3	13	4	15
Day 5	7	15	3	14	4	16

RESULTS AND DISCUSSION

The results as shown in Tables 1-5 revealed the noticed trends in the comparison of rheological properties of the drilling fluid with increasing temperature and concentration. The mud samples were beneficiated with Barite (for weight increase), KOH (for increased pH), and CMC (for increased viscosity) to know if the cellulose would perform in the presence of other additives, the results displaying the pH, mud weight and rheological properties are shown in Table 6.

Table 6: Result of the control and sample A muds in the presence of Barite-CMC-KOH.

Mud samples Barite-CMC-KOH	Mud Density (lb/gal)		pH		PV, μ_p (cp)		YP, τ_y (lb/100 sqft)	
	Control	Sample A	Control	Sample A	Control	Sample A	Control	Sample A
1 – 1 – 1	8.7	8.5±0.2	9.17	8.39±0.02	10	10±1	24	25±2
2 – 2 – 2	8.7	8.5±0.2	9.44	8.85±0.05	10	12.5±0.5	42	36±1
3 – 3 – 3	8.7	8.6±0.2	9.63	9.45±0.25	13	16±2	54	47±2
API SPEC	8.65 – 9.60		9.5 – 12.5		8 – 10		24 – 30	

The viscometer dial reading has its values from 0 to 300. With reference to the Tables 4 and 5 above, it can be seen that the maximum dial reading of the control mud is 34, while that of sample mud is 29. Also, with increasing temperature, the control and sample muds have an average plastic viscosity of 4.3(±0.3) cp while the average yield point of the control mud is 17(±0.3) lb/100sqft which is higher than the sample mud yield point which is 12(±0.4) lb/100sqft.

Plastic viscosity on drilling fluid indicates the capability of the mud to rapidly drill and exit through the bit while yield point is used to evaluate the ability of the mud to lift cuttings in the annulus. From the above tables, both sample mud and control mud have equal and low plastic viscosity, hence they will rapidly move through the bit, but the control mud has a higher ability to carry cuttings better than the sample mud because of a higher yield point value.

CONCLUSION

Based on this study, the success of cellulose extracted from waste paper as a water-based mud viscosifier, the following conclusions have been drawn:

1. Generally, increase in the concentration of the liquid (cellulose) sample gotten from paper has slight effect on the rheological properties of the drilling fluid.
2. With increasing temperature, there was an insignificant increase in the plastic viscosity of both the sample and control muds, but the yield point of the control mud was higher than that of the sample mud.
3. The density of the drilling mud prepared with the sample was constant (8.7 lb/gal).
4. With increasing sample concentration, the pH of the drilling fluid continually increases, meaning, the sample is slightly alkaline.
5. In the presence of other additives (Barite, KOH and CMC), both the sample mud and control mud performed similarly on the average.

Also, comparing the results (Table 6) from this study with API Laboratory Specification standard, it showed clearly that cellulose gotten from paper proved technically capable and could be a suitable local substitute for standard viscosifiers.

RECOMMENDATION

It is recommended that more research work should be carried out to test other properties of the drilling fluid prepared with liquid (cellulose) gotten from paper to further prove its usefulness as a continuous phase in water based mud.

ACKNOWLEDGEMENTS

The authors would like to thank Petroleum Technology Development Fund (PTDF) Chair in Department of Petroleum Engineering, University of Ibadan who provided laboratory support where the experiments was carried out. The authors would also like to thank the anonymous reviewers for the time and constructive comments.

NOMENCLATURE

t	Time (s)
ρ	Density (lb/gal)
τ	Shear Stress (Pa)
μ	Apparent Viscosity
τy	Yield Point (lb/100 ft^2)
μp	Plastic Viscosity (cp)
θ_N	Viscometer Dial reading (degree)
PV	Plastic Viscosity (cp)
N	Rotor Speed (rpm)
T	Temperature (^oF)
YP	Yield Point (lb/100 ft^2)