International Journal of
Science and Engineering Investigations
vol. 9, issue 99, April 2020
Received on April 17, 2020
ISSN: 2251-8843

Enhancement of Afuze-Ikhin Clay for Use as Bentonite for Drilling Fluid Operations

C. W. Okologume[1], J. A. Nwanade[2]
[1,2]Department of Petroleum Engineering, Federal University of Petroleum Resources, Effurun, Nigeria
([1]okologume.wilfred@fupre.edu.ng)

Abstract-Clay is a predominantly used material for drilling in Nigeria and most part of the oil producing regions of the world. Nigeria has relied on the use of imported bentonite clay for use as drilling fluid. In an attempt to utilize and improve local content, this research evaluated the Afuze-Ikhin clay sample via a series of laboratory analysis to ascertain its suitability for the preparation of drilling mud. The results revealed that the clay has poor viscosity even though it has a fair pH value. The clay sample was enhanced by the addition of different percentages of washing soda concentrations in a controlled system at different speeds (i.e. rpm). Gaussian model was then used to describe the behavior of the clay mixture; showing the relationship between viscosity and time as a function of sodium carbonate concentration and speed of agitation (rpm). At the end of the experimental analysis, it was observed that the viscosity of the clay sample was greatly improved between 2% and 4% concentration of sodium carbonate and at 300rpm as well as 600rpm. This particularly demonstrated that the Afuze-Ikhin clay can be enhanced for the preparation of drilling mud utilized for drilling operations.

Keywords- *Bentonite, Drilling Mud, Beneficiation, Viscosity*

I. INTRODUCTION

This template, Drilling mud is a mixture of clay, water, chemicals and certain other additives that facilitates the removal of cuttings from the well and performs cooling along with lubrication of the drill bits during any drilling operation. It is any fluid that is used in a drilling process in which that fluid is circulated or pumped from the surface, down the drill string, through the bit, and back to the surface via the annulus [7]. The drilling fluid used is usually characterized by weighty materials such as barites and viscosifiers such as bentonite clay which creates a perfect rheological property for the drilling fluid to serve its purpose during drilling.

Nigeria is blessed with abundant oil and gas reserves, but has continually resorted to the importation of drilling fluid when she equally possesses the resources in abundance to produce drilling fluid [1]. Nigeria have consumed, and are still consuming, large quantities of clays for drilling muds, most of which are imported even with the presence of large reserves of clay in Nigeria [12]. Clay minerals are layered aluminosilicates consisting of stacks of negatively charged two-dimensional layers [3]. Clays of several kinds and grades abound throughout Nigeria's sedimentary basins and on the basement [6]. Drilling fluid constitutes a large ratio of oil field chemicals consumed annually [2]. However, Nigerian clays are found to be calcium-based and have little or no minerals of the montmorillonite group, this affect the rheological properties adversely and hence they do not meet the American Petroleum Institute (API) specification for use as drilling muds. Even though, the bentonite clay available in the country is characterized by a poor viscosity due to the presence of calcium oxide [9], it can be enhanced to meet the API standards or specifications [4]. Bentonite is categorized as sodium bentonite or calcium bentonite, subject to the dominant exchangeable cation [11]. The neglect of the use of the bentonite clay available in the country, has resulted to a considerable upsurge in the cost of drilling operations [10]. This is disadvantageous to the county’s economy and has also caused a failure in the actualization of the essential goal of the petroleum industry which is “minimizing cost and optimizing profit”. This study nonetheless is aimed at enhancing the performance of a Nigerian local clay termed “Afuze-Ikhin” clay inherent in the southern region of the country, precisely Edo state, for use as drilling mud. The study evaluates a vital rheological property of drilling mud which is the viscosity. However, this work is limited to laboratory analysis in order to determine the suitability of locally available clay for drilling fluids formulation. The research is restricted to bentonite samples from Nigeria where the local clays were basically sought.

II. MATERIALS AND METHOD

A. *Sample Collection and Preparation*

The Afuze-Ikhin clay sample collected from the soil site was sun-dried to remove moisture and then pounded with the aid of a mortar and pestle to reduce the particle size and increase the surface area. The pounded clay sample is then put in a furnace for further drying to remove the possible moisture content in sample. After drying, the sample is taken to mill for further grinding to get the desired particle size. A hammer mill is mounted vertically and is designed to have two funnels. The upper funnel serves as the clay sample inlet while the bottom one serves as the clay sample outlet. The mill has a hammer at the center which is driven by an electric motor part of the mill.

The function of the hammer is to continuously reduce the particles of the clay to obtain the desired size. Below the hammer is a sieve with mesh of size 75 μm. The mesh is changeable and the mesh size used determines the size of the clay particle to be obtained. After passing through the mill, the clay gotten is packaged for experiment. A sample of Afuze-Ikhin clay mixture is illustrated in Fig. 1.

Figure 1. Afuze-Ikhin clay sample

Four different samples were prepared to determine the viscosities of the clay samples (A-D) at periodic time intervals and at different speed of agitation;

i. Sample A: 100g of clay/1400ml of distilled water.
ii. Sample B: 100g of clay/1400ml of distilled water + 2 wt. % $Na_2CO_3(s)$
iii. Sample C: 100g of clay/1400ml of distilled water + 4 wt. % $Na_2CO_3(s)$
iv. Sample D: 100g of clay/1400ml of distilled water + 6 wt. % $Na_2CO_3(s)$

B. Evaluation of Mud Mixture clay Sample

17.5g of bentonitic clay was measured by the use of a weighing balance in 350ml measuring cylinder. Subsequently, 17.5g × 5 (i.e. 87.5g) was obtained using weighing balance and 1750ml entire mixture with water was measured using a measuring cylinder. The mixture yielded a mud density of about 8.6ppg.when measured with a mud balance. Similarly, 87.5g of Afuze-Ikhin clay was measured using a weighing balance and was mixed with water using a mud mixer for 30 minutes to obtain a homogeneous mixture. The sample of the mixture was poured into a measuring cylinder and allowed for 30 minutes to test if the mixture would separate into its constituent components, i.e. clay and water, but it did not. This is illustrated in Fig. 2.

Figure 2. Clay sample mixtures allowed staying for 30mins in a measuring cylinder

The Afuze-Ikhin clay mixture weighs 8.4 ppg as against 8.6 ppg for the same measurement of bentonite and water. A Marsh Funnel was then used to get the apparent viscosity for each of the clay mixtures (that is bentonite and Afuze-Ikhin clay). However, the marsh funnel apparent viscosity for Afuze-Ikhin clay mixture is 26 seconds, while that of bentonite is 33 seconds. The pH of each of the sample was taken such that Bentonite gives 8.8 and the Afuze-Ikhin clay mixture gives 8.6.

Since the density of Afuze-Ikhin mud is 8.4 ppg and coupled with the fact that the apparent viscosity of the mixture is 26 seconds, there was need for it to be enhanced so that its rheological properties will become adequate to be used as a drilling circulation fluid.

C. Evaluation and determinination of best fit

The following models in the preceding subsection were used in determining the best fit.

1) Gaussian model

A Gaussian model is a statistical distribution where observation occur in a continuous domain e.g. time and space. In a Gaussian process, every point in some continuous input space is associated with normally distributed random variable. Gaussian functions are important in statistical modelling because of properties inherited from the normal. For example, if a random process is modelled as a Gaussian process, the distribution of various derived quantities can be obtained explicitly. Such quantities include the average value of the process over a range of time and the error in estimating the average using sample values at a small set of time. Gaussian function is shown by the equation below.

$$F(t) = ae^{-(t-b)^2/2c^2} \quad (1)$$

2) Exponential model

An exponential function is of the form:

$$f(t) = \exp(t) \quad (2)$$

$$f(t) = ab^t \quad (3)$$

$where\ a = b^c$ and a, b and c are constants.

The input variable t occurs as an exponent hence the name. The exponential model is used to model a relationship in which a constant change in the independent variable gives the same proportional change (i.e. percentage increase or decrease) in the dependent variable.

3) Exponential power model

An exponential power function simply called Power function is similar to exponential function. In a power function, the independent variable t is raised to a (constant) power c but in an exponential function, the independent variable is the exponent while the base is the constant.

III. RESULTS AND DISCUSSION

The results of the experiment performed on the Afuze-Ikhin clay samples are as shown in the tables below. The time versus the viscosity obtained from the Ostwald viscometer are well illustrated in the table. The time was measured in seconds while viscosity, in Pa.s.

During the course of the experiment, it was observed that the pH of A Afuze-Ikhin clay mixture was 8.6 while that of bentonite was 8.8. Since the standard pH measurement for drilling mud varies between 8 and 12.5, it demonstrates that Afuze-Ikhin clay is suitable to be used as drilling mud. Moreover, there is a need for the Afuze-Ikhin clay to be enhanced by the addition of washing soda. The results on viscosity of the mixture versus the different time intervals are illustrated in Tables 1 to 3.

TABLE I. RESULTS OF THE EXPERIMENT ON SAMPLES (A- D) AT 300 RPM

Time (s)	100g (clay)	2wt% Na_2CO_3	4wt% Na_2CO_3
5	0.263	0.31	0.142
10	0.27	0.292	0.154
15	0.231	0.263	0.162
20	0.221	0.254	0.171
25	0.215	0.227	0.172
30	0.213	0.135	0.187
35	0.208	0.119	0.183

TABLE II. RESULTS OF THE EXPERIMENT ON SAMPLES (A- D) AT 600 RPM

Time (s)	100g (clay)	2wt% Na_2CO_3	4wt% Na_2CO_3	6wt% Na_2CO_3
5	0.425	0.355	0.356	0.099
10	0.415	0.379	0.362	0.097
15	0.404	0.336	0.365	0.093
20	0.399	0.326	0.365	0.093
25	0.365	0.323	0.362	0.093
30	0.355	0.314	0.358	0.093
35	0.353	0.286	0.356	0.092

TABLE III. RESULTS OF THE EXPERIMENT ON SAMPLES (A- D) AT 900 RPM

Time(s)	100g (clay)	2wt% Na2CO3	4wt% Na2CO3	6wt% Na2CO3
5	0.44	0.436	0.231	0.022
10	0.446	0.447	0.224	0.025
15	0.463	0.452	0.196	0.027
20	0.46	0.461	0.191	0.029
25	0.44	0.455	0.164	0.042
30	0.44	0.455	0.164	0.042
35	0.43	0.452	0.146	0.044

Thus, both speed of agitation and concentration of sodium carbonate are significant both as variables and in interaction in the analysis of viscosity of clay while time is the least significant as a variable but may be significant in interaction with both Na_2CO_3 concentration and speed of agitation.

A. Result of the analysis using data-driven model

By using the equations, (1 – 3) and solving the constants, the following tables and graphs were obtained.

Tables 4, 5 and 6 demonstrate the various numerical fit data for data-driven models for control at 300 rpm, 600 rpm and 900 rpm respectively. The R^2 of the Exponential model is undefined as against 1.0 for Gaussian model. This showed that the Gaussian model describes the behavior of the viscosity of the clay sample for control at 300rpm.

TABLE IV. NUMERICAL FIT DATA FOR DATA-DRIVEN MODEL FOR CONTROL AT 300 RPM

Models	a	b	c	R-squared
Gaussian	15.48	-907.2	448.6	1.0
Exponential	0.2597	0.009273	-	

TABLE V. NUMERICAL FIT DATA FOR DATA-DRIVEN MODEL FOR CONTROL AT 600 RPM

Model	a	b	c	R-squared
Gaussian	0.4217	-21.14	108.3	1.0

TABLE VI. NUMERICAL FIT DATA FOR DATA-DRIVEN MODEL FOR CONTROL AT 900 RPM

Models	a	b	c	R-squared
Gaussian	0.4264	17.5	68.32	1.0

Similarly, the exponential model has the line of best fit as shown in Fig. 3. However, Fig. 4 and Fig. 5 also illustrate the adequate fitting of the Gaussian numerical model.

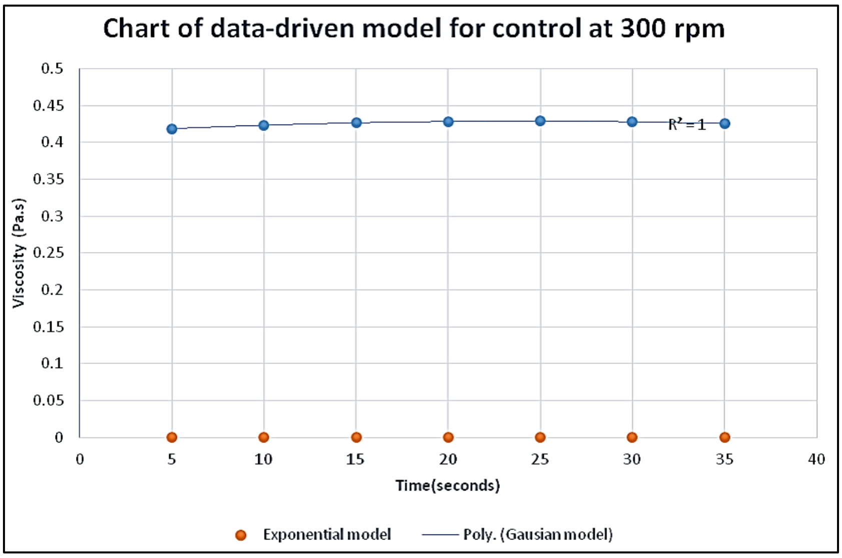

Figure 3. Chart of data-driven model for control at 300 rpm

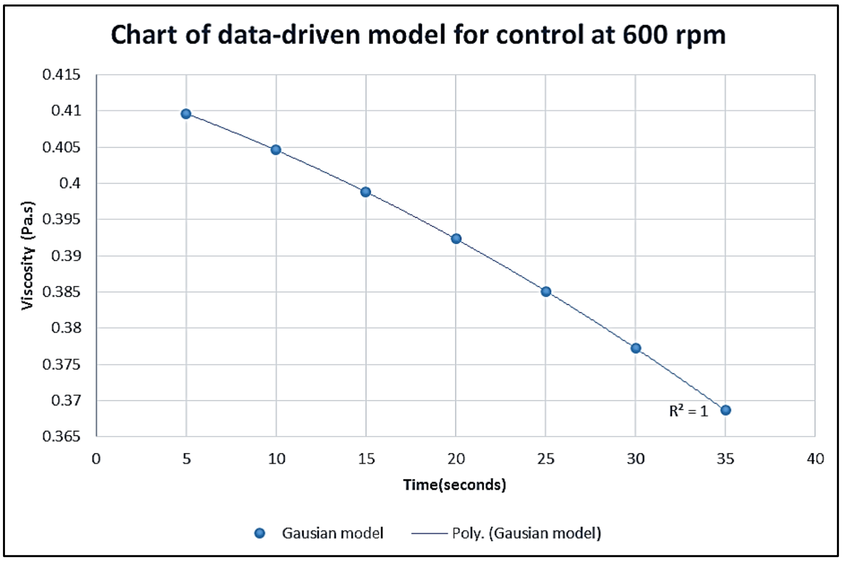

Figure 4. Chart of data-driven model for control at 600 rpm

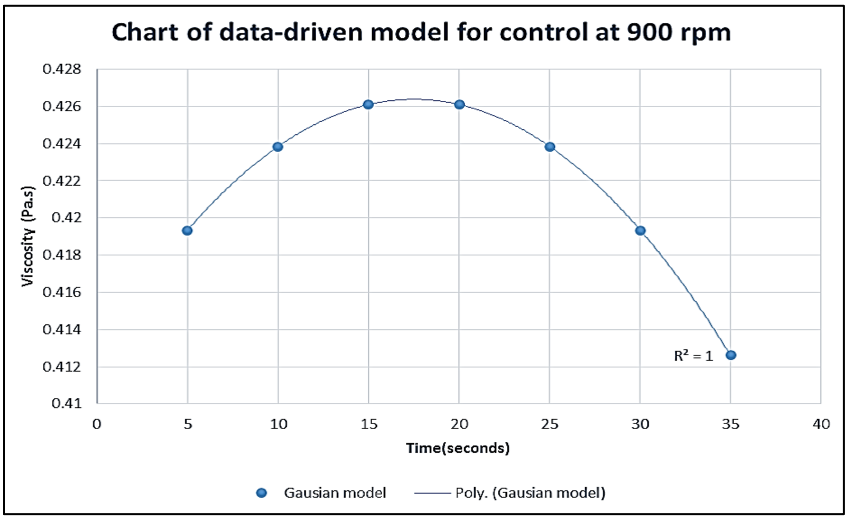

Figure 5. Chart of data-driven model for control at 900 rpm

From Table 7, the R^2 of the Gaussian model data fit (2wt, 4wt, 6wt percentage of Na_2CO_3 at 300 rpm are 1 as against 0.988 and 0.999 respectively. This showed that the Gaussian model describes the behavior of the viscosity of the clay sample for control at 300rpm and has a line of best fit as shown in Fig. 6.

TABLE VII. GAUSSIAN MODEL DATA FIT (2WT, 4WT, 6WT) AT 300 RPM

Gaussian model	a	b	c	R-squared
(2wt.%Na2CO3)	0.2838	6.367	29.26	1
(4wt.%Na2CO3)	0.1735	39.77	67.83	0.998
(6wt.%Na2CO3)	0.0697	-41.8	61.89	0.999

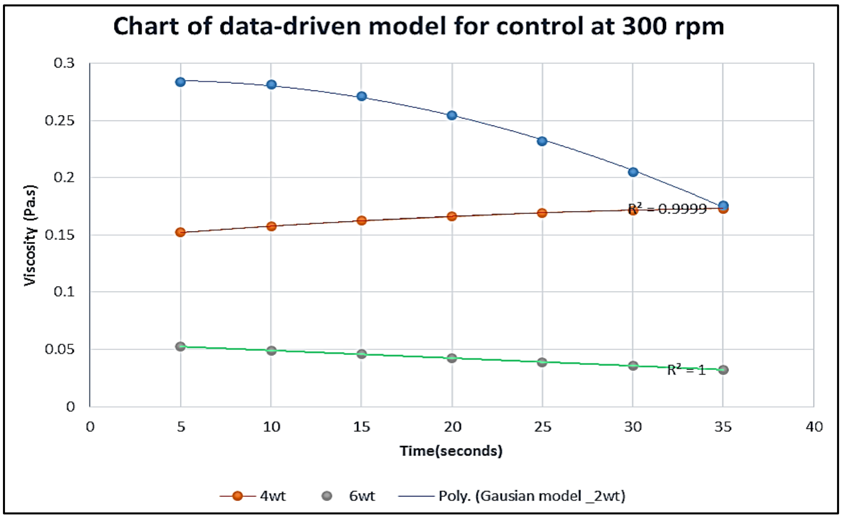

Figure 6. Chart of data-driven model for 2wt, 4wt and 6wt. % Na_2CO_3 at 300 rpm

From Table 8 and Fig. 7, the R^2 of the Gaussian model data fit (2wt, 4wt, 6wt percentage of Na_2CO_3 at 600 rpm are 1 as against 1 and 0.989 respectively.

The 2wt and 4wt percentage concentration of Na_2CO_3 curves from the chart, improves the viscosity of the clay mixture as shown in Fig. 7. Nonetheless, the 6wt percentage concentration of Na_2CO_3 curve showed a non-appreciable increase in the viscosity of the clay mixture.

TABLE VIII. GAUSSIAN MODEL DATA FIT (2WT, 4WT, 6WT) AT 600 RPM

Gaussian model	a	b	c
(2wt. %Na2CO3)	0.3474	-7.007	84.24
(4wt. %Na2CO3)	0.3414	19.18	90.66
(6wt. %Na2CO3)	0.0932	-20.51	179.5

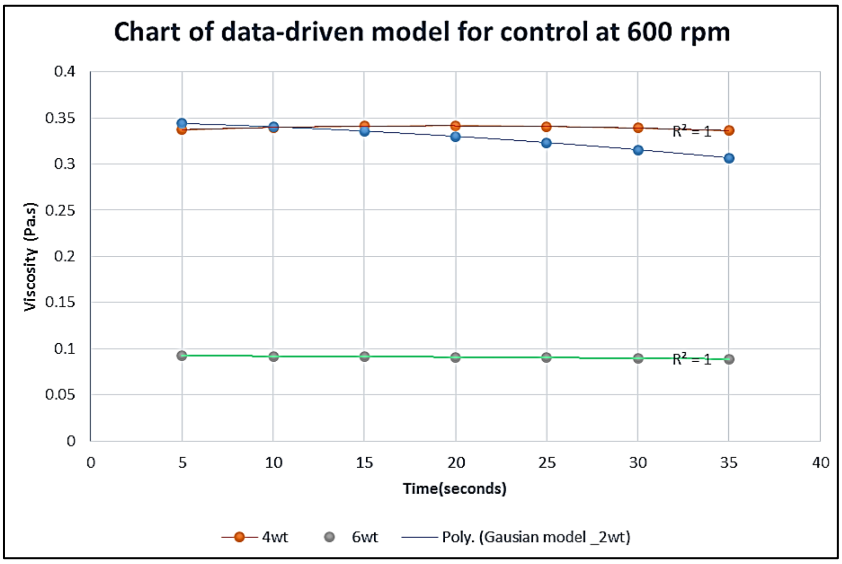

Figure 7. Chart of data-driven model for 2wt, 4wt and 6wt. % Na_2CO_3 at 600 rpm

From Table 9 and Fig. 8, the R^2 of the Gaussian model data fit (2wt, 4wt, 6wt percentage of Na_2CO_3) at 900 rpm are 1 as against 1 and 0.999 respectively. This showed that the Gaussian model describes the behavior of the viscosity of the clay sample for control at 900rpm.

TABLE IX. GAUSSIAN MODEL DATA FIT (2WT, 4WT, 6WT) AT 900 RPM

Gaussian model	a	b	c
(2wt. %Na2CO3)	0.4287	24.13	87.05
(4wt. %Na2CO3)	7.72E+07	-1856	420.7
(6wt. %Na2CO3)	0.04786	52.52	48.98

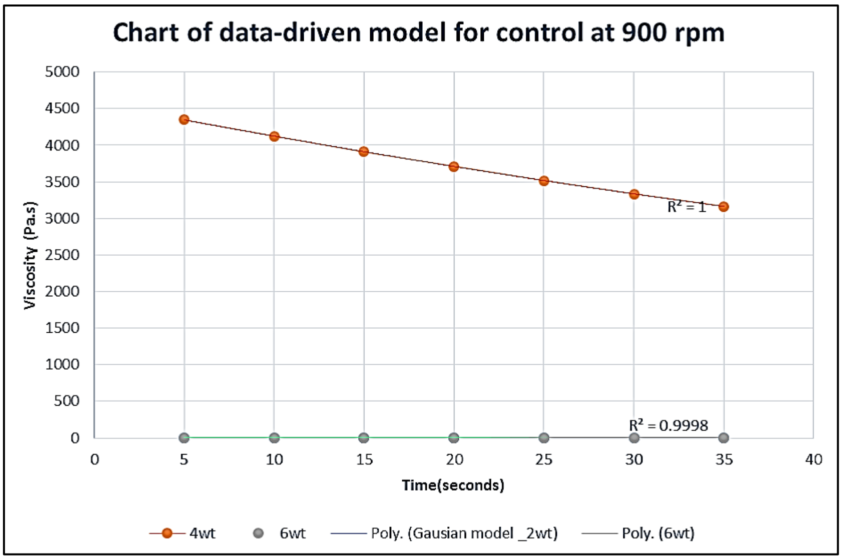

Figure 8. Chart of data-driven model for 2wt, 4wt and 6wt. % Na_2CO_3 at 900 rpm

B. Summary of findings from the results

- The Afuze-Ikhin clay viscosity can be enhanced as a function of sodium carbonate concentration, time and speed.
- Graphically, the relationship between sodium carbonate concentration and viscosity can describe the behavior of the clay sample.

- The Afuze-Ikhin clay sample is suitable to be used as drilling fluid in the industry upon improvement with washing soda.
- The viscosity of the clay sample can be described at any time interval using the Gaussian model.

IV. CONCLUSION

The results of this work have revealed that Afuze-Ikhin clay which can be obtained from the Southern part of Nigeria, possess a poor rheological property (viscosity). Consequently, it cannot be effectively used for the preparation of drilling mud to be used in the oil industry. The viscosity and other properties of the Afuze-Ikhin clay do not satisfy the American Petroleum Institute (API) specifications. However, when improved with various concentrations of washing soda (sodium carbonate), there was an exchange of ion. The calcium ion in the clay samples is replaced with sodium ion and this greatly altered the viscosity. Thus, the results obtained have demonstrated the positive enhancement of Afuze-Ikhin clay through beneficiation with different concentration of sodium carbonate.

The kinetic study of the process showed that the Gaussian model appropriately describes the performance of the clay samples as greater number of R2 fall under Gaussian model. Moreover, the exponential model could not adequately describe the behavior of the clay sample. This is because; the graphical representation of the control showed a decreasing rate in viscosity within the required range of speed of agitation unlike that of the Gaussian model.

Therefore, the optimum operating parameters for enhancing the clay are Na_2CO_3 concentration of 2 to 4wt % and speed of agitation of 300 to 600 rpm.

REFERENCES

[1] O. R. Afolabi, O. D. Orodu, and E. V. Efeovbokhan, “Properties and application of Nigerian bentonite clay deposits for drilling mud formulation: Recent advances and future prospects”, Applied Clay Science, 143, pp. 39–49, 2017.

[2] O. E. Agwu, A. N. Okon, and F. D. Udoh, “A review of Nigerian bentonitic clays as drilling mud”, Paper SPE-178264-MS Presented at the Nigeria Annual International Conference and Exhibition. Society of Petroleum Engineers, Lagos, pp. 1–18, 2015.

[3] R. I. Anderson, H. C. Greenwell, L. Suter, M. R. Jarvis and V. P. Coveney, “Towards The Design Of New And Improved Drilling Fluid Additives Using Molecular Dynamics Simulations”, An. Acad. Bras. Ciênc. vol.82 no.1 Rio de Janeiro, https://doi.org/10.1590/S0001-37652010000100005, 2010.

[4] T. U. Apugo-Nwosu, I. A. Mohammed-Dabo, A. S. Ahmed, G. Abubakar and S. I. Ayilara, “Studies on the Suitability of Ubakala Bentonitic Clay for Oil Well Drilling Mud Formulation”, British Journal of Applied Science and Technology, 1(4), 152-171, 2011.

[5] H. C. Darley and G. G. Gray, “Composition and Properties of Drilling and Completion Fluids”. Gulf Publishing Co 5th edn, Houston Texas, USA; 643, 1988.

[6] O. A. Falode, O.A. Ehinola, P. C. Nebeife, “Evaluation of Local Bentonitic Clay as Oil Well Drilling Fluids in Nigeria”, Applied Clay Science 39, 19-27. Available online at www.sciencedirect.com, 2007.

[7] F. Growcock and T. Harvey, “Drilling Fluids Processing Handbook”, Gulf Professional Publishing, Pages 15-68, (http://www.sciencedirect.com/science/article/pii/B9780750677752500032), 2005.

[8] O. O. Owolabi, A. B. Oriji and J. A. Ajienka, “Effect of Temperature and Salt on the Rheological Properties of Locally Produced Drilling Muds”, SPE – NAICE 1991, Benin, Edo State, Nigeria 11 – 23, 1991.

[9] O. M. Nweke, E. O. Igwe and P. N. Nnabo, “Comparative Evaluation of Clays from Abakaliki Formation with Commercial Bentonite Clays for Use as Drilling Mud”, African Journal of Environmental Science and Technology. Retrieved from http://www.academicjournals.org, 2015.

[10] A. Omole, O. A. James, F. Olugbenga, S. Malomo and A. O. Oyedeji, “Investigation into the Rheological and Filtration Properties of Drilling Muds Formulated with Clays from Northern Nigeria”, Journal of Petroleum and Gas Engineering, 4(1), 1-13. Retrieved from http://www.academicjournals.org/JPGE, 2013.

[11] W. C. Okologume and A. E. Akinade, “Comparative Study of Basic Properties of Mud Prepared with Nigerian Local Clay and Mud Prepared with Foreign Clay: A Case Study of Abbi Clay Deposit", International Journal of Engineering and Technologies, Vol. 8, pp. 61-71, 2016.

[12] S. G. Udeagbara, S. O. Ogiriki, F. Afolabi and E. J. Bodunde, “Evaluation of the Effectiveness of Local Clay from Ebonyi State, Nigeria as a Substitute for Bentonite in Drilling Fluids”, International Journal of Petroleum and Gas Engineering Research, Vol.3, No.1, pp.1-10, 2019.

How to Cite this Article:

Okologume, C. W. & Nwanade, J. A. (2020). Enhancement of Afuze-Ikhin Clay for Use as Bentonite for Drilling Fluid Operations. International Journal of Science and Engineering Investigations (IJSEI), 9(99), 58-64. http://www.ijsei.com/papers/ijsei-99920-08.pdf