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Rheological Effect of Temperature for Base Weighted Mud Formulation

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ABSTRACT
The aim of this study is toinvestigate the rheological effect of temperature for base weighted mud formulation.The rheological behavior of drilling fluids plays a critical role in ensuring efficient drilling operations. Drilling fluids are divided into two different categories depending on their content. Because water-based mud (WBM) is the most common drilling fluid for both offshore and onshore areas, water-soluble polymers (WSPs) are preferred in drilling fluids. Water-based drilling fluids consist mainly of water and clay and are considered a suspension. Oil-based drilling fluids consist mainly of base oil and water emulsion. A range of additives is also added to influence properties such as density, viscosity, and wettability. The cutting suspension and lifting ability of the mud is the most important functions. Conventional based muds are made of Wyoming bentonite dispersed in water or oil as continuous phase in the presence of synthetic additives to enhance its property. The focus is to improve the properties of local based muds with biopolymers and Nanoparticles (Multiwall Carbon nanoparticles and Bamboo raw and modified) to meet API standards and serve as a substitute to the expensive and environmentally unfriendly synthetic muds and modeling the pressure losses in vertical pipes to observe the effect of nanoparticle addition on pressure loss. Modified Aluu Clay was enhanced with a composite of Arabic Gum and Cocoyam starch, Sodium Hydroxide, Potassium Chloride and weighted with barite to create a base mud formulation. 0.1g, 0.2g, 0.5g and 0.8g MWCNT and BRM were added to create new formulations and rheological readings were taken at room temperature, 60^{o}C and 94^{o}C. Results showed that at room temperaturethe yield point exponentially increased.
Keywords:*Rheological, drilling, temperature, base weighted mud, formulation,*

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I. INTRODUCTION

Drilling fluids, commonly referred to as drilling muds, are indispensable components in the drilling operations of oil, gas, and geothermal wells. These fluids serve several crucial functions that ensure the success and safety of drilling processes. Primarily, drilling fluids are used to cool and lubricate the drill bit, transport rock cuttings to the surface, maintain wellbore stability, control subsurface pressure, and prevent blowouts (Rahman, 2018). Without properly designed drilling fluids, the drilling operation could suffer from inefficiencies, increased costs, and potential environmental or safety hazards (Gureay et al., 2019).

The performance of a drilling fluid is largely determined by its rheological properties**,** which describe how the fluid flows and deforms under applied forces (Muherei et al., 2022). Among these properties, viscosity is of paramount importance because it dictates the ability of the fluid to suspend and transport cuttings, minimize fluid loss, and maintain hydraulic pressure throughout the wellbore (Kuna, 2023). Proper viscosity ensures that cuttings are effectively carried out of the well, preventing blockages and stuck pipes, while also contributing to efficient bit cooling and stable wellbore formation.

II. MATERIALS AND METHODS

2.1 MATERIALS: Clay samples were collected by using hand auger to scoop the clay materials from swamp forest OmuikeAluu in Rivers State, Nigeria. The samples were collected from Ikwerre local government at location with latitude 6.97514^{o} N and longitude 3.74545^{o} E between Aluu and Isiokpo, Ikwerre, Rivers state, Nigeria.

2.2 METHODS: The raw clay samples were purified to remove all gross impurities in the sample. Samples were ground using the electric grinder to reduce the particle size to less than 60 μm. The powder was wet sieved using distilled water to separate the clay from impurities such as rocks and sand. The resulting slurry was

allowed to sediment and decanted. Wet sieved clay was be air - dried to reduce the moisture content and thereafter be oven dried at 70 ºC in an electric oven until a constant weight was achieved.
Clay beneficiation was carried out according to Akinwande et al (2014). The beneficiating agent that was employed was Na2CO3 at concentrations ranging from 1.1 M to 5.5 M. The selection of the concentration range was based on previous research by Salawudeen et al. (2014). The processed clay (100 g) was dispersed in 100 ml of distilled water to form slurry and the slurry was preheated to 60 ºC for 5 minutes. The beneficiating agent (100 ml) was added to the preheated slurry and the mixture heated to 90 ºC between 60 and 80 mins under continuous stirring. The slurry formed was sun-dried to reduce the moisture content and later oven-dried in an electric oven
(Surgifield Laboratory oven, SM9053A) at 80 ºC until a constant weight was achieved. The dried clay was ground to less than 100 microns using an electric grinder (Marlex Appliances PVT Limited).
The equipment used in this study to achieve the objectives are Zeiss Scanning electron microscope, Weighing balance, Sand Retort Kit, Multi-Mixer, Mud balance, variable speed rheometer in Materials Science and Engineering and Petroleum Engineering Laboratories of African university of Science and Technology, Galadimawa, Abuja.
Scanning electron microscope (SEM): The scanning electron microscope is an electron microscope that produces a surface image of samples with a focused beam of electrons is allowed to interact with the atoms of the samples thereby producing signals that display the surface topography and composition of the sample. Energy dispersed spectroscopy (EDS) involves the elemental analysis and chemical characterization of a sample through some source of X-ray excitation from a sample caused by allowing a focused beam of the electron into the sample

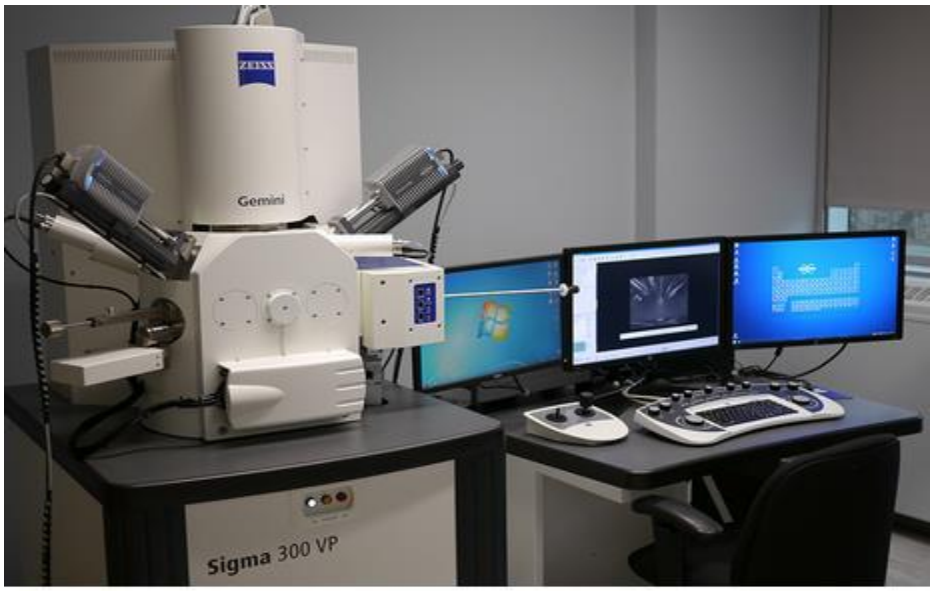

Figure 2.1: ZEISS SEM Equipment for SEM AND EDS Characterizations

Weighing balance: Weighing scale or balance is a device used to measure the mass or weight of samples.
Sand retort kit: The volume of sand sized particles in the drilling fluid is determined by a sand content kit. Materials with size greater than 74 μm (200 mesh) are sand particles and not fit for drilling usage.
Multi-mixer: To get accurate results from drilling fluid experiments, drilling mud samples in the process of their preparation are mixed thoroughly to create an homogeneous mixture. Multimixers are used to mix drilling mud samples in preparation for laboratory tests.
Mud balance: Mud balance is used to determine the density or weight of a given volume of liquid or drilling mud. It is are calibrated in pounds per gallon (Ib/gal), specific gravity (SG, kg/m3), Pounds per cubic feet (Ib/ft3),Pounds per square inch per 1000feet (Ib/in2/1000ft).
Variable speed viscometer: Variable speed viscometers are used to study rheological or flow behaviour of drilling mud suspensions. It gives the shear stress and shear rate relationship of drilling fluids with respect to time and temperature. Properties such as plastic and apparent viscosity, yield point, gel strength can be determined by the use of an 8 speed viscometer.

The materials used in the drilling mud formulations and their functions are given in the table below:

Table 2.1: Components of Drilling Mud Formulations.

Component	Functions
Modified Gombe Clay	Local based clay to be suspended in water
Barite	Weighting agent
Cocoyam Starch	Viscosifier and fluid loss additive
millet Starch	Viscosifier and fluid loss additive
Gum Arabic	Viscosifier and fluid loss additive
Caustic soda(NaOH)	PH Modifier
Potassium Chloride(KCl)	Shale Inhibitor additive
Water	The continous phase of the drilling mud sample
Carbon Nanotubes	Fluid loss additive

Experimental design

The experimental design is in three stages and is shown below;

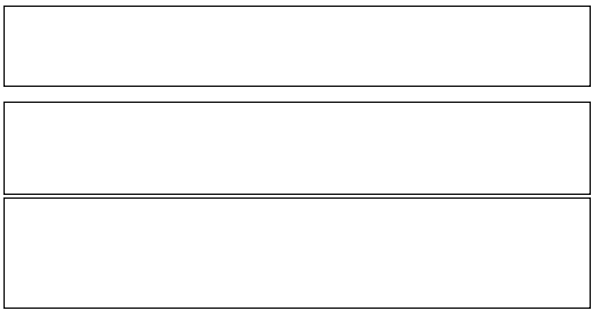

Figure 2.2: Experimental design

Blank mud preparation

- A water-based mud is prepared with 24.5g of Gombe clay and 350ml of water. Density, Apparent and plastic viscosity, Yield point, Gel strength, solid content and thixotropy is taken immediately and after 24 hours to observe aging effect.
- The previous step is repeated with imported bentonite.

Natural viscosifiers addition

- Three new mud formulations having 2g, 5g and 8g Corn starch in Hydrated Gombe clay mud samples is prepared and the density, apparent and plastic viscosity, Yield point, Gel strength, solid content and thixotropy is measured.
- The above procedure is repeated with Gum Arabic to give three formulations.
- Various new formulations are created using composite of gum arabic and cassava starch and their density, apparent and plastic viscosity, yield point, gel strength, solid content and thixotropy were measured.

Addition of nanoparticles

- The formulation in the previous stage with optimum property values close to API standard is selected
- Three new formulations by adding 0.1g,0.2g, 0.5g, 0.8g CNTs each to the previously selected mud formulation and thixotropic, filter and gel test is done at Room Temperature, 60oc and 94oF and the final mud formulation is selected.

Rheology and hydraulics

Rheology of the finally selected Gombe mud is taken and the hydraulic pressure losses is determined using existing pressure loss models.

Procedures

Procedure for preparation of mud with and without additive

A water base mud was prepared by dispersing 24.5g of Gombe clay in 350ml of water and stirred with a multi-mixer.

Procedure to determine mud density

- Mud mixture with or without additives was prepared and stirred with a multi-mixer and their temperature recorded.
- Then after, the mud balance base was placed on a flat level surface.
- The fill cup was filled with the mud sample. The lid was placed on the cup with care taken to prevent trapped air or gas. Some mud that expelled through the hole on the cap helped to ensure the cup is filled.
- The expelled mud was cleaned off the cup and arm and the balance placed on the knife edge. Afterwards, the rider was moved along the arm until the cup and arm was balanced. This is indicated by the bubble on the arm.
- Finally, the mud density was read at the edge of the rider towards the mud cup as soon as the bubble stabilizes.

Procedure for solid content measurement

- The sand content tube was filled to the indicated mark with drilling mud
- Afterward, the wash bottle was used to add water to the tube to raise its level to the next mark. While ensuring that the mouth of the tube was closed, the tube was shaken vigorously.
- Then after was the mixture poured onto a screen and water added to the tube to aid flushing of all mixtures onto the screen.
- The screen was flushed as well to make sure no sand particle is left on the mud remaining on the screen.
- The funnel was fitted upside down over the top of the screen. The assemble was inverted and the tip of the funnel placed on a mouth of a glass measuring tube
- Water is poured onto the screen to further flush sand left in the funnel.
- Finally, the tube containing the flushed sand and water mixture was allowed to settle to get a clear separation of the sand and water and the sand content is measured.

Procedure to determine rheology using 8-speed viscometer

- The test mud sample was placed in the sample cup and the rotor sleeve immersed in the mud to the fill line by raising the platform and tightening the locknut on the platform.
- Afterwards, the switch was pressed to turn on the device.
- The sample was mixed on the "STIR" setting for 10 seconds.
- Then after the knob was rotated to one of the speed settings and allowed to stabilized and the readings recorded. This is repeated for other speed settings and readings were taken from highest RPMs to lowest RPMs.

Procedure to determine gel strength using 8-speed viscometer

- The sample was mixed on "STIR" for 10 seconds
- Then after, the knob was rotated to "GEL" and the power was immediately shut off.
- As soon as the rotation of the sleeve stopped, the clock was set to 10 seconds after which the power was turned on and the maximum deflection was recorded as the dial reading which the 10 seconds gel strength is.
- To get the gel strength for 10 minutes, the sample was re-stirred for 10seconds and the second and third step above was repeated by waiting for 10 minutes.

Calculations for rheology and API standards

According to Rahman, (2020), apparent viscosity, plastic viscosity and yield point can be calculated with the expressions stated below.

Plastic viscosity, $\mu_p = \theta_{600} - \theta_{300}$ (2.1)

Where Θ_{600} and Θ_{300} is dial reading at 600 rpm and 300rpm

Apparent viscosity, $\mu_a = \frac{300\theta_N}{N}$ (2.2)

Where Θ_N is dial readings in degrees and N is the speed of rotor in revolution per minute.

Yield point $\tau y = \theta_{300} - \mu_p$ (2.3)

Shear stress, τ in pounds per 100 ft^2 ($lbf/100ft^2$) = $\frac{\text{Force}}{\text{Area}}$ = Dial reading x 1.067

Shear rate, in per seconds (sec^{-1}) = 1.701x Revolution per minute (RPM)

(Ofite manual, 2019).

Table 2.2: API Standards for Drilling Fluid Properties.

Properties	**API Standard**
Viscometer reading at 600RPM	minimum of 30cp
Density	8.65-9.5 Ib/gal
Plastic Viscosity	Less than 65 cp
Yield Point	15 to 45 Ib/100sq ft
Gel Strength at 10 seconds	3 to 20 Ib/100sq ft
Gel Strength at 10 Minutes	8 to 30 Ib/100sq ft
Filtrate Loss	15 ml max

III. Results and Discussion

3.1 Rheology

Fifteen mud formulations with and without additives were prepared for sensitivity check on rheological properties to get the optimum or base formulation. 20 g of modified Aluu clay was dispersed in 400 ml of fresh water to give properties before and after aging for 24 hours obtained from experiments.

Table 3.1: Property Values of Mud Formulations without Additives

Properties	At Start	After 24 Hours
θ_{600}	4	4.5
θ_{300}	3	3
Plastic Viscosity	2	2.5
Apparent Viscosity	2.5	2.75
Yield Point	2	1.5
Gel Strength at 10 Seconds	2	2
Gel Strength at 10 Minutes	2	2
Density, lb/gal	9.7	9.7
Temperature, ^{o}C	28	25
Sand Content	< 1%	< 1%

Table 3.1 above shows little or no difference in the properties of the mud after 24 hours of aging. Rheological properties and sand content of the blank mud formulation before and after aging were quite low with no potential threat to drilling operations according to API requirements. However, the mud formulated still needs some improvements. To enhance the rheological properties, new muds formulations laden with Millet Starch, Arabic Gum, and Cocoyam Starch additives were prepared and their properties were tested at room temperature.

In Table 3.2, it is observed that as the mass of millet starch increased from 2 to 15 g the plastic viscosity increased accordingly. However, Yield point and gel strength at 2 and 5 g remained almost constant but increased a little upon addition of 8 and 15 g concentrations. As the concentrations of Gum Arabic increased between 2 to 20 g, Plastic and Apparent viscosities increased accordingly. Gel strength was observed to decrease with the addition of 2, 5 and15g concentration, the gel increased to its previous value as before and at 20 g, it increased a little at 10 minutes gel. These properties of the mud formulations with additive proved to have changed on the addition of various additives but not yet up to the optimum standard required for drilling purposes. This suggests that new formulations that meet optimum requirements are required. It is observed that the mud sample was more responsive and suited to Arabic gum compared to Millet starch. Since the values already obtained are not sufficient enough, composites of additives in muds were prepared. The mud formulation with 20 g Arabic gum and 20 g Cocoyam starch showed tremendous improvement on plastic and apparent viscosities and yield point. However, the gel strength values remained poor.

Table 3.2: Mud Formulations with Additives

Drilling Mud Formulations	θ_{600}	PV	YP	10’	10’’	Density, lb/gal	Temperature, ^{o}C
Hydrated Mud + 2g of Millet Starch	5	2.5	1	1	1	8	30
Hydrated Mud + 5g of Millet Starch	7	3.5	1	1	1	8.5	30
Hydrated Mud + 8g of Millet	8.5	5	-1	1	1.5	8.75	29.4

Starch							
Hydrated Mud +10g of Millet Starch	9	6.5	-1.5	1	2	8.8	29
Hydrated Mud +15g of Millet Starch	10	8.5	-2	1.5	2.5	8.82	28.5
Hydrated Mud +20g of Millet Starch	10.5	12	-2.5	2	3	8.85	27.5
Hydrated Mud + 2g of Arabic Gum	5	2.9	0.2	0.5	0.5	8.86	29.5
Hydrated Mud + 5g of Arabic Gum	6	3.5	0	1	1	8.7	29.7
Hydrated Mud + 8g of Arabic Gum	8	4.5	0	1	1	8.79	30.5
Hydrated Mud +10g of Arabic Gum	10	5.5	1	1	1	8.91	30.2
Hydrated Mud +15g of Arabic Gum	18.5	11.5	-2.5	1	1	8.95	28.5
Hydrated Mud +20g of Arabic Gum	29.5	18.5	-7.5	1	2.5	8.98	28.2
Hydrated Mud +15g of Cocoyam Starch	5	2.9	0.2	1	1	8.8	29.5
Hydrated Mud +10g of Cocoyam Starch + 15g of Arabic Gum	26	14	-1	1	1	8.93	26
Hydrated Mud +20g of Cocoyam Starch + 20g of Arabic Gum	42.5	23.5	-4.5	1	1	9	30.5

PV =Plastic Viscosity, YP= Yield Point, 10'= 10 seconds gel strength .10"= minutes gel strength, Θ_{600} =Dial Reading at 600RPM.

Table 3.3: Rheological Properties of Drilling Mud Formation for Millet Additive

Rheological Properties of Mud	2g	5g	8g	10g	15g	20g
Plastic Viscosity, cp	2.5	3.5	5	6.5	8.5	12
Gel at 10 Seconds, lb/100 sqft	1	1	1	1	1.5	2
Gel at 10 Minutes, lb/100 sqft	1	1	1.5	2	2.5	3

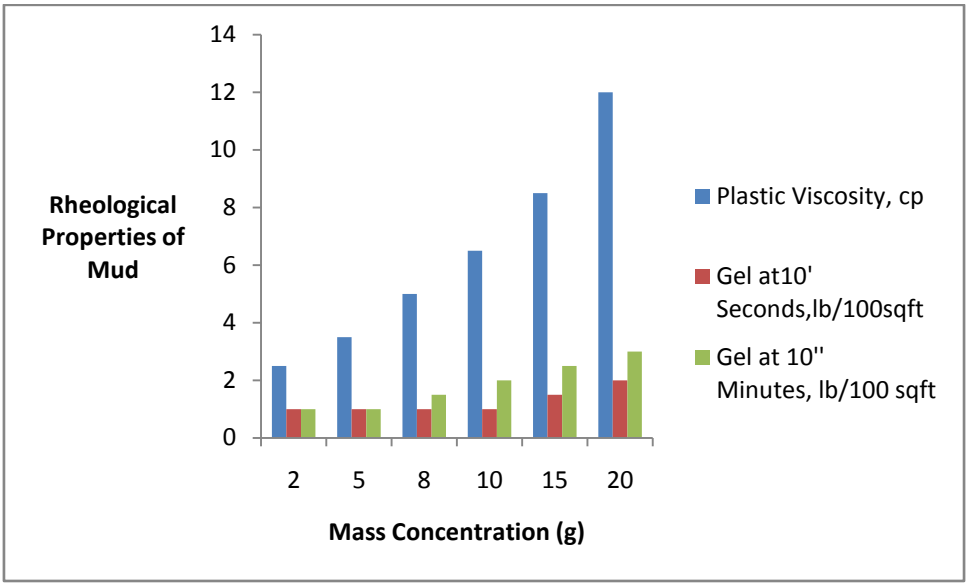

Figure 3.3: Rheological Properties of Mud before and After Addition of Millet Starch at Various Concentrations of Millet (g)

Figure 3.3 shows the relationship between the rheological properties of mud before and after addition of millet starch and concentrations of millet in grams. In the 2g to 20g plastic viscosity highest, but highest in 20g, Gel at 10' and 10'' has the same in 2g and 5g. From 8g to 20g Gel at 10'' is higher than Gel at 10', but, highest in 20g in both Gel at 10' and 10''.

Table 3.4: Rheological Properties of Drilling Mud Formation for Arabic Gum Additive

Rheological Properties of Mud	2g	5g	8g	10g	15g	20g
Plastic Viscosity, cp	2.9	3.5	4.5	5.5	11.5	18.5
Gel at 10 Seconds, lb/100 sqft	1	1	1	1	1	1
Gel at 10 Minutes, lb/100 sqft	1	1	1	1	1	2.5

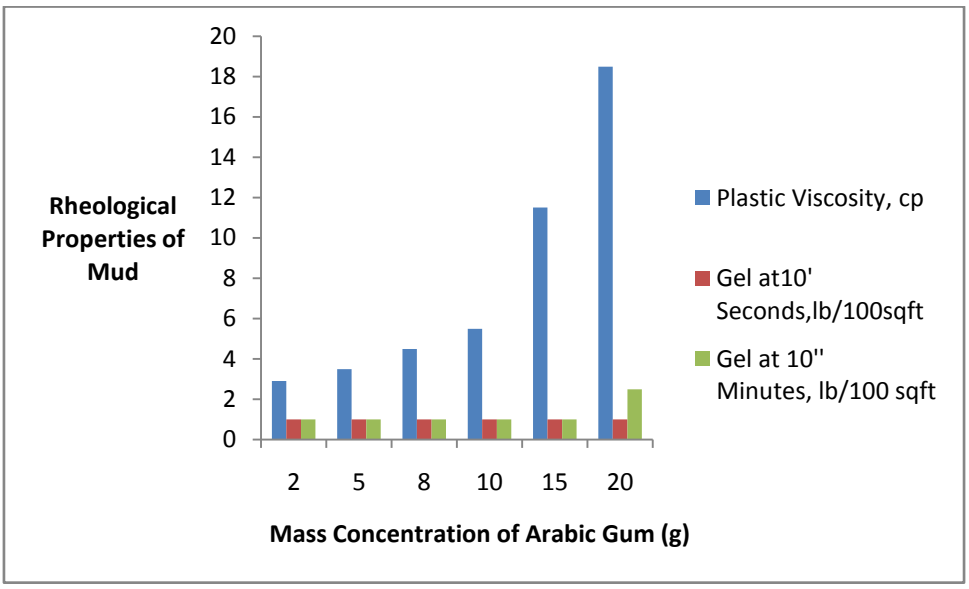

Figure 3.4: Graph of Rheological Properties of Mud before and After Addition of Arabic Gum at Various Concentrations of Arabic Gum (g)

Figure 3.4 illustrates the relationship between the rheological properties of mud before and after addition of Arabic gum and concentrations of Arabic gum in grams. In the 2g to 20g plastic viscosity has the highest, but highest in 20g, Gel at 10' and 10'' has the same in 2g and 15g. In 20g Gel at 10'' is higher than Gel at 10'.

3.2 Effect of temperature on rheology of base weighted mud formulation

The base weighted mud formulation was subjected to a temperature of 25, 60 and 94^{o}C. Figures 4.5, 4.6 and 4.7 show the effect of temperature on plastic viscosity, yield point, and gel strength. Plastic viscosity and yield point are reduced with an increase in temperature. Plastic viscosity decreased as the weighted mud sample temperature increased from 25 to 60^{o}C. This behavior is probably because some of the particles in the mud sample have been destroyed due to thermal effects. However, at 94^{o}C, plastic viscosity being very high could be the result of the evaporation effect leaving a larger ratio of the concentration of solids to liquids. Hence, the solid particles attracted each other more closely. Gel strength at 10 seconds and 10 minutes increased as temperature increased from 25 to 94^{o}C. The yield point and gel strength are measures of attractive forces between particles in the mud. An increase in temperature of the mud from 25 to 94^{o}C increased to yield point and gel strength. This is probably due to the evaporation effect that has occurred during the heating process from 25^{o}C to 94^{o}C causing an increase in the ratio of attracted solid particles to the liquids.

Table 3.5: The Effect of Temperature on Plastic Viscosity and Yield Point of Base Weighted Mud Formulation

Temp (^{o}C)	Plastic Viscosity, cp	Yield Point
25	22	0.2
60	9	8.1
94	70	80

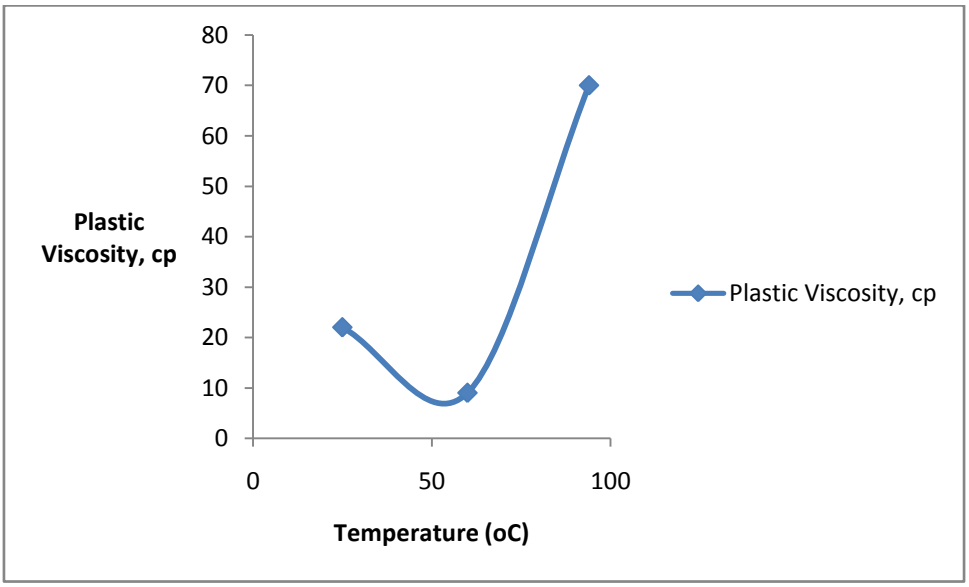

Figure 3.5: Plastic Viscosity against Temperature for Base Weighted Mud Formulation

Figure 3.5 shows the relationship between plastic viscosity and temperature. It indicates that the viscosity decreased as 9cp at temperature of 60^{o}C and exponentially increased with temperature.

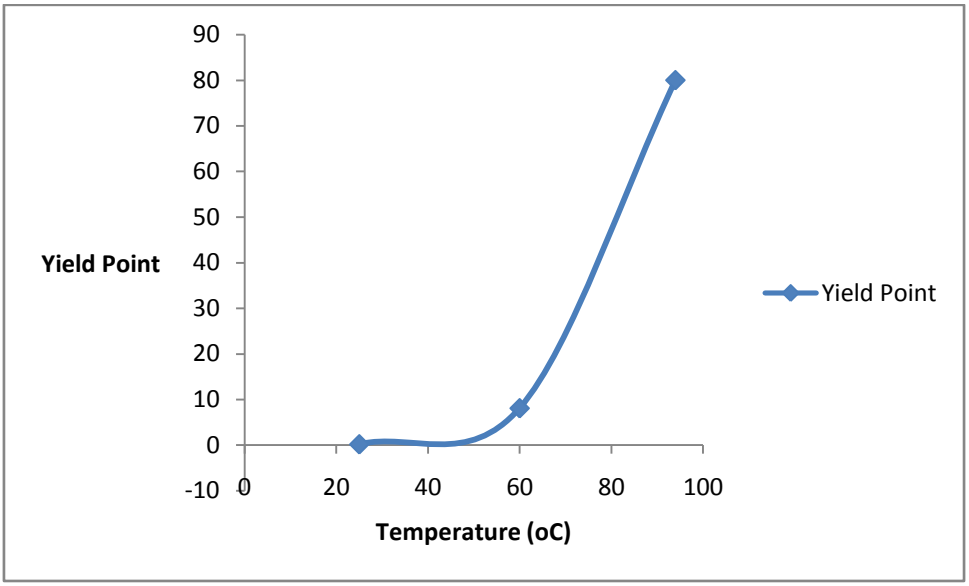

Figure 3.5: Yield Point versus Temperature for base weighted mud formulation

Figure 3.5 illustrates the relationship between yield point and temperature. It shows that the yield point exponentially increased with temperature.

Table 3.6:The Effect of Temperature on Plastic Gel Strength of 10 Seconds and 10 Minutes of Base Weighted Mud Formulation

Temp (^oC)	Gel 10 Seconds, lb/100 sqft	Gel 10 Minutes, lb/100 sqft
25	5	7
60	7	8
94	10	11

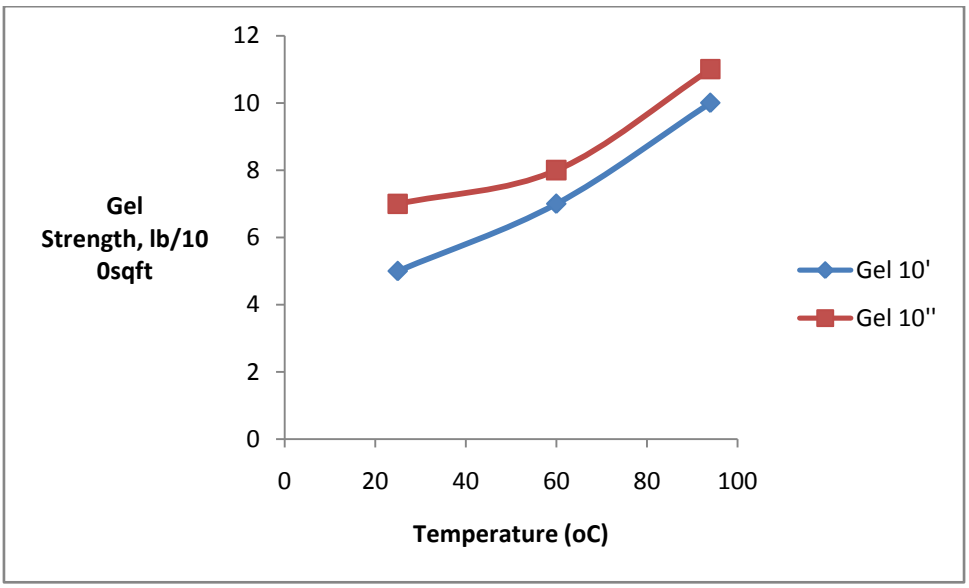

Figure 3.6: Gel Strength versus Temperature for Base Weighted Mud Formulation

Figure 3.6 demonstrates the relationship between gel at 10' second and 10'' minutes and temperature. It indicates that the gel strength of 10' seconds and 10'' minutes, exponentially increased with temperature, but higher in gel at 10'' minutes.

3.2.1 Effect of Nanoparticles on Rheology of Base Weighted Mud Formulations.

Nanoparticles applications in drilling fluid have helped to improve the rheological of the fluid. 0.1, 0.2, 0.5 and 0.8 g Multiwall CNTs and activated bamboo carbon (BRM) were added to the various base weighted mud samples to investigate their effect on the rheological properties of the mud sample at temperatures of 25, 60 and 94^oC. Table 4.6 and 4.7 shows their effect on the weighted drilling mud formulations.

Table 3.7: Effects of MWCNT on drilling mud

MWCNT Conc. g	Temperature (^oC)	Dial Reading@600RPM	Dial Reading@300 RPM	PV, cp	Yp	Gel 10’	Gel 10”
0	26	47	24	23	1	5	8
	60	23	15	8	7	6	9
	94	218	148.5	69.5	79	12.5	15
0.1	26	39.5	18.5	21	-2.5	5	9
	60	21.5	13	8.5	4.5	5	7
	94	218	145	73	72	30.5	29.5
0.2	26	39	18	21	-3	5	8
	60	20.5	12.5	8	4.5	5	7
	94	207	155	52	103	25	24
0.5	26	37	20	17	3	5	8
	60	24	14.9	9.1	5.8	5	8
	94	240	188.5	51.5	137	24	21
0.8	26	36.2	19	17.2	1.8	5	7.5
	60	24	14	10	4	5	8.5
	94	251.5	177	74.5	102.5	22.5	19.5

Table 3.8: Effects of BRM on drilling mud

BRM Conc. g	Temperature (^oC)	Dial Reading@600RPM	Dial Reading@300 RPM	PV, cp	Yp	Gel 10’	Gel 10”
0	26	47	24	23	1	5	8
	60	23	15	8	7	6	9
	94	218	148.5	69.5	79	12.5	15
0.1	26	43.5	18	25.5	-7.5	5.5	8.5
	60	24	14.5	9.5	5	5.5	7.5
	94	224	142	82	60	26.5	25
0.2	26	40.5	17.5	23	-5.5	5	6
	60	25.5	15.5	10	5.5	4	5
	94	207	142.5	64.5	78	18	17
0.5	26	40	21	19	2	4.5	7
	60	21	13	8	5	5	8
	94	220	147	73	74	17.5	16.5
0.8	26	39.5	18	21.5	-3.5	4.5	6.5
	60	23	13.5	9.5	4	5	8.5
	94	224	145	79	66	17	15

3.2.2 Sensitivity of Different Concentration of MWCNT and BRM on Gel.

Figure 4.8 to 4.9 shows the effect of MWCNT and BRM on gel at 26, 60 and 94^{o}C. The figures show that at 26^{o}C there is little or no changes in gel strength at 10 seconds and 10 minutes. Gel strength at 10 seconds and 10 minutes was improved by the addition of nanoparticles at all concentrations at 94^{o}C. However, the increase was most significant between 0.1 and 0.2 g of MWCNT and BRM. Afterward, there is a decline in gel strength as the concentration increases to 0.8 g. MWCNTs formulations produced gel greater than BRM formulations mostly. It is observed at 94^{o}C that the CNTs act as thinner causing a reduction in plastic viscosity and gel strength in the mud as it’s concentration increases beyond 0.2g. This means that CNTs concentrations beyond 0.2g would be too excessive and reduce cutting suspension ability at 94^{o}C. An estimate of 0.1g MWCNT formulation is selected for further analysis.

Table 3.9: Effect of MWCNT and BRM on 10 Seconds gel at 26°C

Source of Carbon	0	0.1	0.2	0.5	0.8
BRM	5	5.5	5	4.5	4.5
MWCNTS	5	5	5	5	5

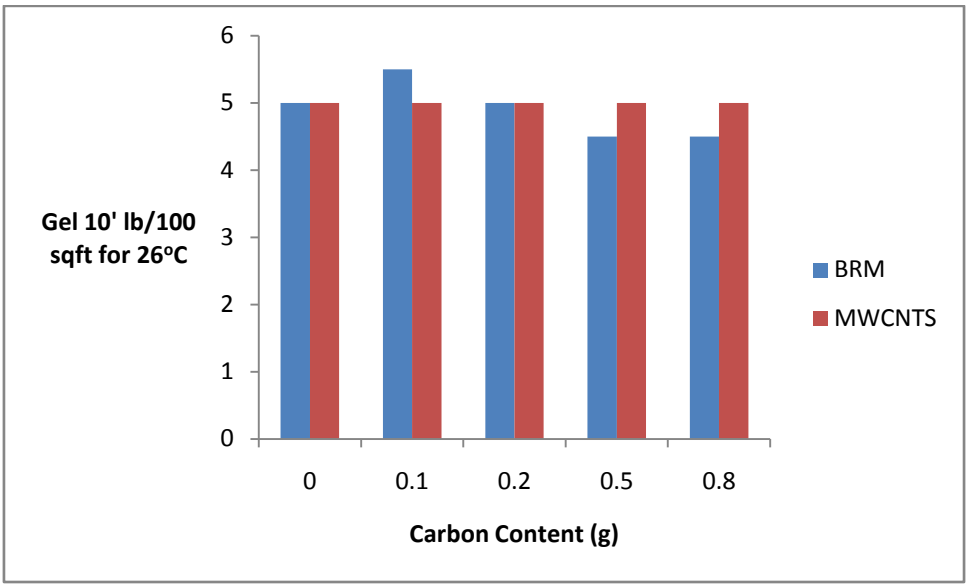

Figure 3.9: Effect of MWCNT and BRM on 10 seconds gel at 26°C

Figure 3.9 shows the relationship between gel at 10' seconds at 26°C with carbon content. It indicates that the gel strength at 10' seconds in carbon content 0g and 0.2g for BRM and MWCNTs are the same, in the gel strength of BRM is higher than that of MWCNT at carbon content 0.1g, the gel strength MWNCT is higher than the of BRM at the carbon contents of 0.5g and 0.8g.

Table 3.10: Effect of MWCNT and BRM on 10 minutes gel at 26°C

Source of Carbon	0	0.1	0.2	0.5	0.8
BRM	8	8.5	6	7	6.5
MWCNTS	8	9	8	8	7.5

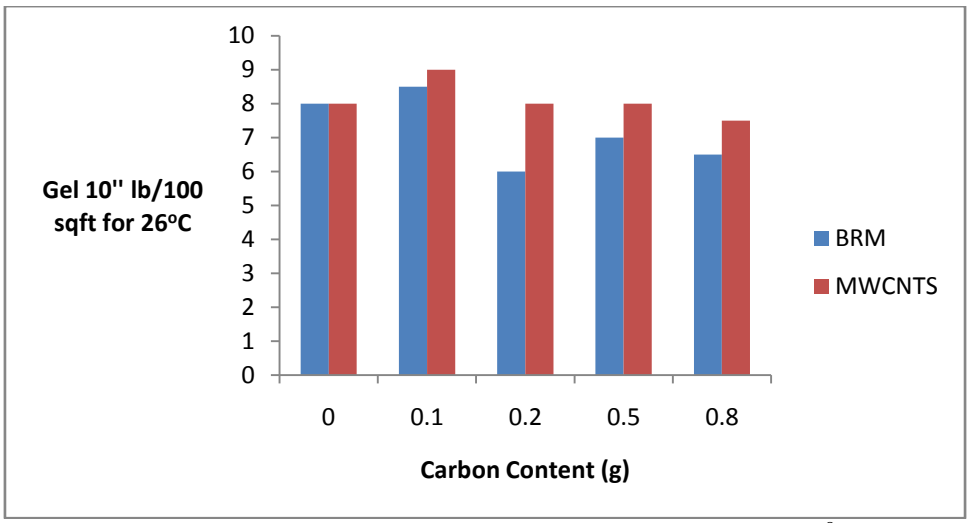

Figure 3.10: Effect of MWCNT and BRM on 10 minutes gel at 26°C

Figure 3.10 illustrates the relationship between gel at 10'' minutes at 26^{o}C with carbon content. It shows that the gel strength at 10'' minutes in carbon content 0g for BRM and MWCNTs are the same, the gel strength of MWCNT is higher than that of BRM at carbon content 0.1g, 0.2g, 0.5g and 0.8g.

Table 3.11: Effect of MWCNT and BRM on 10 seconds gel at 60^{o}C

Source of Carbon	0	0.1	0.2	0.5	0.8
BRM	6	5.5	4	5	5
MWCNTS	6	5	5	5	5

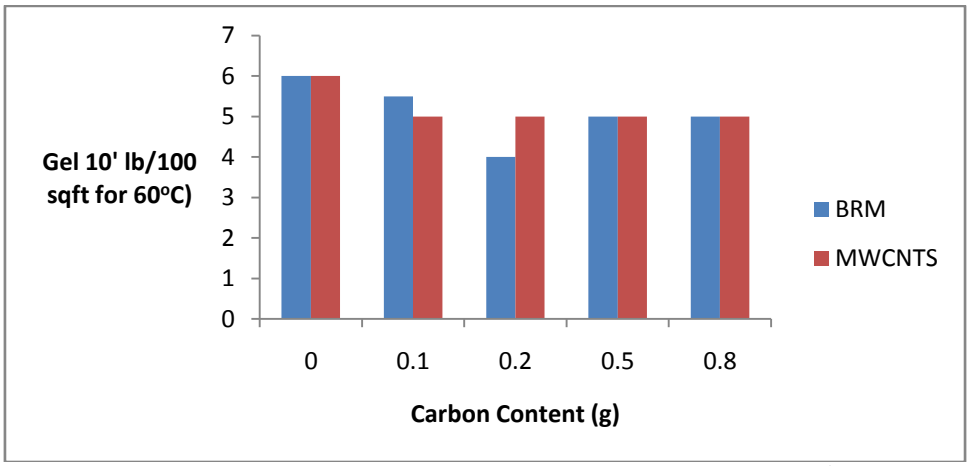

Figure 3.11: Effect of MWCNT and BRM on 10 seconds gel at 60^{o}C

Figure 3.11 demonstrates the relationship between gel at 10' seconds at 60^{o}C with carbon content. It indicates that the gel strength at 10' seconds in carbon content 0g, 0.5g and 0.8g for BRM and MWCNTs are the same but highest in carbon content of 0g, the gel strength of BRM is higher than that of MWCNT at carbon content 0.1g, and MWCNT is higher than BRM at carbon content of 0.2g.

Table 3.12: Effect of MWCNT and BRM on 10 Minutes gel at 60^{o}C

Source of Carbon	0	0.1	0.2	0.5	0.8
BRM	9	7.5	5	8	8.5
MWCNTS	9	7	7	8	8.5

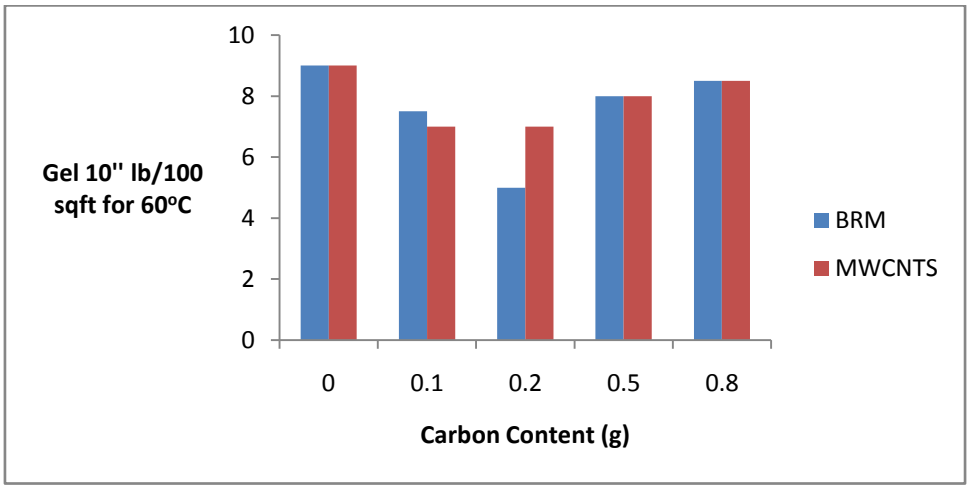

Figure 3.12: Effect of MWCNT and BRM on 10 minutes gel at 60^{o}C

Figure 3.12 shows the relationship between gel at 10'' minutes at 60^{o}C with carbon content. It indicates that the gel strength at 10'' minutes in carbon content 0g, 0.5g and 0.8g for BRM and MWCNTs are the same but

highest in carbon content of 0g, the gel strength of BRM is higher than that of MWCNT at carbon content 0.1g, and MWCNT is higher than BRM at carbon content of 0.2g.

Table 3.13: Effect of MWCNT and BRM on 10 Seconds gel at 94°C

Source of Carbon	0	0.1	0.2	0.5	0.8
BRM	12.5	26.5	18	17.5	17
MWCNTS	12.5	30.5	25	24	22.5

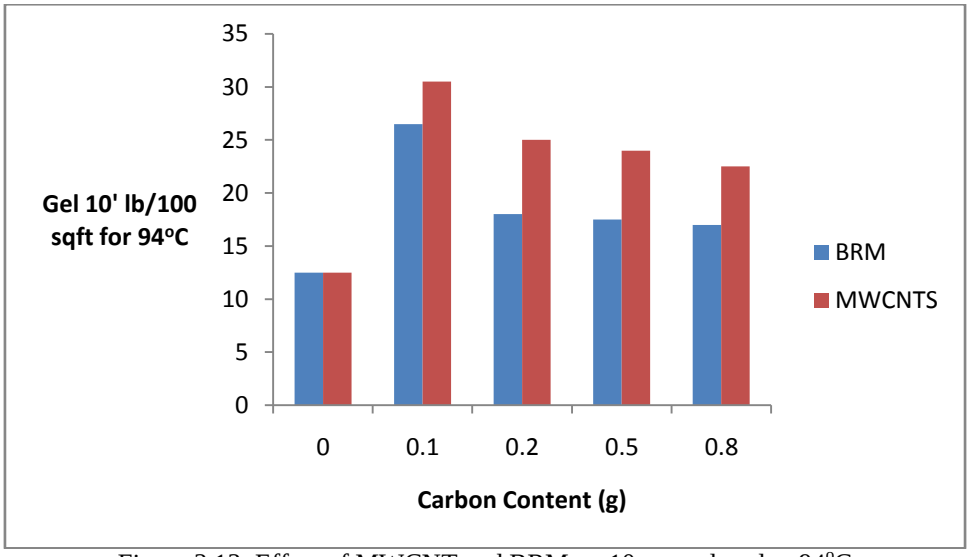

Figure 3.13: Effect of MWCNT and BRM on 10 seconds gel at 94°C

Figure 3.13 illustrates the relationship between gel at 10' seconds at 94°C with carbon content. It indicates that the gel strength at 10' seconds in carbon content of 0g, for BRM and MWCNTs are the same. The gel strength of MWCNT is higher than that of BRM at carbon content 0.1g, 0.2g, 0.5g and 0.8g, but highest in 0.1g carbon content.

Table 3.14: Effect of MWCNT and BRM on 10 Minutes Gel at 94°C

Source of Carbon	0	0.1	0.2	0.5	0.8
BRM	15	25	17	16.5	15
MWCNTS	15	29.5	24	21	19.5

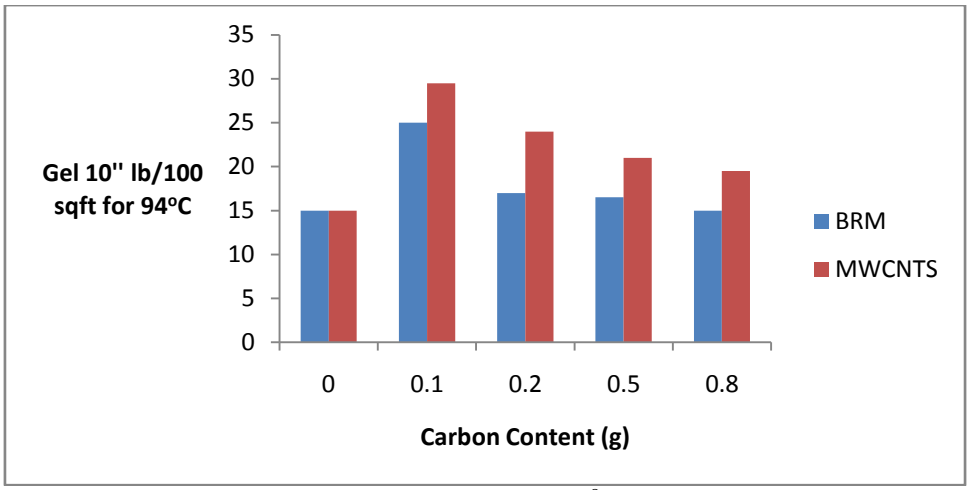

Figure 3.14: Effect of MWCNT and BRM on 10 minutes gel at 94°C

Figure 3.14 shows the relationship between gel at 10'' minutes at 94°C with carbon content. It indicates that the gel strength at 10'' minutes in carbon content of 0g, for BRM and MWCNTs are the same. The gel strengths of

MWCNT are higher than that of BRM at carbon content 0.1g, 0.2g, 0.5g and 0.8g, but highest in 0.1g carbon content.

IV. Conclusion

Based on the analysis of this research it has helped to improve gel strength of local biopolymer based Aluu clay and reduce its pressure losses in vertical pipes by addition of Nanoparticles of various sizes.Composites of Arabic gum and cocoyam biopolymers gave better dial reading at 600RPM and plastic viscosity of modified Aluu clay in comparison to formulations having individual polymers of millet starch, cocoyam starch and Arabic gum. Gel readings were still below API standards.MWCNT (multi-walls carbon nanotubes) and BRM (Bamboo raw modified) formulations had little or no significant effect on gel strength at room temperature but gave better gel strength at high temperature in comparison to mud formulations having no CNT. Bingham model was most appropriate to describe MWCNT formulations in comparison to Power law models based on regression's plot values

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