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Modelling and Evaluation of the Effect of Temperature on the Rheological Properties of Drilling Mud Formulated with Local Barite

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Abstract - *This research paper assesses the effect of temperature on the rheological properties of Water-Based and Oil-Based Muds. The Muds were formulated with locally sources barite from 5 locations in Nigeria.Third order polynomial models have been considered to model the rheological properties as a function of SG (Specific gravity) which were generated using least square method and regressed with the Excel GRG (Generalized Reduced Gradient) Non-Linear Forward derivative solver. The absolute mean percentage error of the model data and measured data were calculated for all rheological properties and WBM 10" Gel strength had the highest error of 6.578% followed by OBM Yield Point of 4.443%. WBM Plastic viscosity showed the least error of 0.315%, seconded by WBM 10' Gel strength with error of 0.339%. Findings from this work indicated that barites Samples B3 and B5 are good barites for WBM formulation as their rheology withstood increasing temperature the most and B4 is better for OBM formulation. Also, B1 and B2 will be good for OBM formulation if beneficiated to increase its SG and remove impurities.*

Keywords - *Barite, Modelling, Oil-based mud, Rheology, Water based-mud.*

I. INTRODUCTION

Drilling is an important aspect of the oil and gas sector for without drilling, there is no access to the available natural resources below the earth crust[1]. Around one fifth (15 to 18%) of the total cost (about $1 million) of well petroleum drilling are related to the drilling fluid[2]. The functions of drilling muds include suspending and carrying drill cuttings from the bottom of the wellbore to the surface, cooling and lubricating the drill bit, etc. The success of drilling an oil well is largely dependent on the drilling fluid being used in the drilling process.

The most important properties that differentiates the effectiveness of various drilling fluids in achieving its functions are its density and rheology. The drilling fluid must have sufficient density in order to carry the drill cuttings to the surface. Density also contributes to the stability of the wellbore by increasing the pressure exerted by the drilling fluid in the formation zone down hole.

Weighting materials are compounds that are added to drilling fluid to increase its density and they are used primarily control high formation pressures and prevent explosive release of wellbore fluid from the well, which could lead to a blow out [3]. The choice of weighting agents to be used in drilling fluids is usually determined by many factors. One of the most important factors is to provide low rheology in high density fluids and low sag [4]. There are various types of weighting materials used in drilling fluid formulation, but barite is predominantly used in drilling mud formulation.

Barite is a heavy mineral that normally occurs with Pb-Zn ore, barite vein, baritefluorite vein deposit; strata bound SEDEX-type deposit among other deposits as a gangue mineral, in sedimentary deposits, and rarely in salts [5]. About 80% of barite in the world is used as a weighting material in drilling fluids in oil and gas exploration to suppress high formation pressures and prevent blow out [6], [7], [8]. Interestingly, there are large amounts of barite deposits which can be found in some states in Nigeria. The status of barite mining activities in Nigeria currently shows that the barite quality from different localities proves that Nigeria does not necessarily need to import high grade or any other specification of barite from foreign countries for its usage in the desired industries [9].

One major drilling fluids challenges is to maintain desirable rheological properties. Rheological properties provide assistance in characterizing fluid flow. Rheology is the study of the deformation flow behavior exhibited by fluid material. It is primarily concerned with the use of shear stress and shear rate relationship of drilling fluids. Rheological properties are used to design and evaluate the rig circulating systems (annular hydraulics) and to assess the functionality of the mud system [10]. The rheology of the mud indicates the behavior of the mud and is characterized by: viscosity, plastic viscosity, yield value and gel strength. All these parameters are subject to change under extreme conditions such as high pressure-high temperature or low pressure-low temperature conditions[18].

The effects of temperature and pressure, mud physical and rheological properties of the drilling muds tend to change and as result affect the competence of drilling muds. Formulating a drilling mud that can satisfactorily withstand drilling in high temperature conditions is quite a task, but little devotion is usually offered to right fluids plan and design. Due to the fact that temperature and pressure increases with increase in depth, drilling deeper formation necessitates that drilling fluids for such deeper formations should be able to weather higher temperatures and pressures. Generally, correctly designed drilling muds should be able to accomplish some of the routine functions that are aimed at cost-effective and efficient, drilling programme [11],12]–[15].

Igwilo [12] evaluated and modelled the effects of temperature on Oil Base Mud viscosity using Polynomial Equation. For this Research, the Plastic Viscosity and drilling fluid yield point were modelled using least square method and gaussian elimination method. He generated linear models and polynomials of order 2 for PV and YP respectively of which the Polynomial models gave a better coefficient of regression (R^2) of 99.70% and 99.71% for PV and YP respectively. The Linear model he generated gave a coefficient of regression of 99.17% and 99.11% for PV and YP respectively. From the above R^2 values, he suggested that the polynomial model is a best fit for PV and YP for Oil-based muds.

The performance of 70/30 and 90/10 Oil Water Ratio of Oil Based Mud systems has beencharacterized and evaluated[15]. This characterization was achieved through direct experimental measurements and the performance evaluation was successfully carried out through simulation and experimental studies as well. For this research, various characteristics and behaviours of Oil based muds have been consideredfor proper characterization such as wellbore stability and wellbore collapse of which a drilling should be able to solve through a proper mud weight. Then this research wasnarrowed to Oil-based mud and comparison of known rheology models such as the Newtonian fluid model, Viscoplasticfluid,Bingham fluid (Constant apparent viscosity),Pseudoplastic fluid (Power law, shear thinning fluid) and Dilatant fluid (Shear thickenings fluid) to the rheology of his 90/10 and 70/30 Oil Water ratio of OBM systems at varying temperatures within the range 80oF to 180oF. This allowed proper fluid characterization. It was found out that temperature had a significant effect on the plastic viscosity of 70/30 and 90/10 OBM systems studied. For the temperature effect on the OBM systems and a polynomial model of order 2 was proposed for 70/30 Oil Water ratio OBM and 90/10 Oil Water ratio OBM respectively with R2 of exactly 1 for PV of both Oil water ratio OBM systems.. It was also observed that temperature had more effect on the 70/30 Oil Water ratio OBM system. This is because the 70/30 Oil Water ratio OBM contained more water and also water has a higher specific heat capacity of 4200J/KgK when compared with diesel of 1750J/KgK. Water will retain more heat than oil over time which will lead to mud additives being exposed to high temperature over a longer period. Hence, Mud which retained much heat, will loose viscosity and its yield point lowered.

The effect of temperature on drilling mud properties had been studied in a similar work [16]. For the research, drilling fluids (2 samples) from an offshore rig were collected with the cuttings in it. The mudswerewere subjected to laboratory experiment on increasing temperature and its 600RPM and 300RPM values were recorded for the varying temperatures being subjected to. The YP and PV values were also recorded for each samples and YP/PV ratio calculated. Graphical comparison was made for each sample and experimental and analytical deductions were as follows:

1. For heavy weight fluid (high density) the PV value increased with increase in temperature especially in 74°C but in light fluid (low density) the PV value decreased with increased in temperature. This means that temperature effect on drilling mud depends on the density of the drilling fluid as well. Density which will be controlled by the amount of drilling cuttings especially the fine particles that become part of the mud system.

2.For Mud With high density, some additional chemical material must be addedto improve themud with hightemperature. Meaning temperature had more effect on heavier mud.

This last conclusion appears reasonable as 70/30 Oil water ratio OBM system of the Su WaiAungKhaing research work is heavier than the 90/10 OBM system. Typically, Water is heavier than Oil (diesel) in most cases, hence heavier mud.

The effect of temperature on the rheological propertieswith shear stress limit of iron oxide nanoparticlemodified water-based bentonite drilling muds have been studied [13]. Increasing the temperature from 25°C to 85°C for drilling mud with 6%of bentonite modified with 1% of nanoFe_2O_3 reduced the PV from 45.6cP to 33.6cP meaning that increase in temperature reduces Water Based Mud viscosity.

Upon investigating the effects of Temperature on the Density of Water Based Drilling Mud [14], it was revealed that temperature had an "undoubted huge effect" on drilling mud property, the Water-based bentonite mud reduced in mud weight from 8.85ppg to 8.49ppg by an increase in temperature from 28ºC to 70ºC. The mud weight reduction had its greatest effect from 50ºC to 70ºC with a very sharp decrease, sloping about 60 degrees to the horizontal.

In essence, efficient monitoring and drilling fluid formulation is important for a safe drilling program. Determination of the mud properties requires the experimental examination of the mud system at both the standard API and the high temperature, high pressure conditions at intervals throughout the duration of the drilling process [10]. In this work, experiment was conducted on water-based mud and oil based mud from ambient condition of 80ºF to higher temperatures of 120ºF, 140ºF and 160ºF and the effect of elevated temperature on the rheological properties of water- based mud and oil based mud has been presented.

II. METHODOLOGY

The methodology of this paper is in two classes: laboratory measurements and graphical comparison of measured data with Non-Linear regression in Microsoft Excel to model the performance of mud samples with barite from different location in Nigeria. Water and Oil based mud were formulated with mud additives and locally sourced barites and their rheology measurements were carried out in accordance with API requirement as inTable1, 2 and 3 below, under laboratory conditions temperature of 80ºF, to determine its effectiveness before being exposed to higher temperatures of 120ºF, 140ºF, and 160ºF.

Rheology measurements were carried out in accordance with API standard as shown in Tables 1, 2 and 3 below, under laboratory conditions ambient temperature of 80ºF, to determine its effectiveness before being exposed to higher temperatures of 120ºF, 140ºF, and 160ºF.

Samples Preparation and Characterisation

Five barite samples were obtained from some barite deposit locations in Nigeria. Barite Sample 1 (B1) was gotten from Lessel in Benue state, B2 was from Azara in Nasarawa state, B3 was from Anka in Zamfara state, B4 was from Osina in Cross Rivers state and B5 was gotten Gabu in Cross Rivers. The samples were obtained as lumps,cleaned and crushed to powder.

Specific Gravity (SG) of a liquid or solid substance is the relative density of that substance to the density of water. The specific gravity of barite is the defining property that directly affects the mud weight. For the SG determination, 100g of each barite sample was measured using a measuring cylinder, dried in an oven for 30 minutes and later transferred to desiccators so as to remove any entrained moisture. Kerosene was poured into the Le Chatelier's flask at zero or little above zero mark, and then it was transferred to a regulated water bath at constant temperature and allowed to stabilize for one hour. At the end of the one hour, the Le Chatelier's flask containing kerosene was removed from the bath and allowed to stabilize. The Final measure of kerosene was taken as the Initial Value. 80g of each barite sample was measured then poured into the flask with kerosene; the kerosene in the flask rinsed and stabilized at Final Value. SG was calculated using the corresponding relation, wherein the change in volume was obtained by deducting the Initial Value (ml) from the Final Value (ml).

Moisture Content of the pulverized barite samples was determined with the aid of a measuring cylinder, weighing balance, oven, desiccator, stop watch. To achieve this, 10g each of the barite samples were measured with the aid of weighingbalance and kept in the oven for one hour at a temperature of 105°C.At the end of the drying process, the samples were transferred to desiccators to remove any remaining moisture entrained in the sample.The samples were left kept in the desiccators for one hour before weighing.The difference in initial weight of sample before drying and the weight after drying were used to determine the moisture content in percentage of total weight of each of the samples.

Particles Size determinationwas performed using 75µm sieve.10g of each barite sample was weighed and poured into the mixer containing 350 ml of treated distilled water and allowed to blend for 10 minutes. An empty-dry 75µm sieve was weighed and recorded, and then the blended mixture was then poured into the already weighed sieve.The mixture in the sieve was then washed gently using fresh water from a nozzle for 2minutes, after which the sieves containing the remaining particle were dried and placed inside a desiccator. The sieves were finally removed from the desiccators and reweighed.

Table 1. Result of Barite Characterization

Sample	**B5**	**B4**	**B3**	**B2**	**B1**	**API**
Specific Gravity	4.21	4.19	4.12	3.79	3.70	≥4.2
Moisture Content (Wt.%)	0.284	0.495	0.297	1.287	0.594	≤1.0
Particle Size (% >75µm	1.7	1.00	1.60	4.90	2.90	≤3.0

Mud Formulation

All the drilling mud samples used in this investigation were formulated and tested following the API Recommended Practices [20]. The mud formulation involved mixing several substances to achieve a desired specification of drilling fluid. The components used to formulate drilling fluid can be grouped thus; base fluid, viscosifiers, fluid loss control additives, pH control additives, and weighting agents [21], [22] – [24]. The components will be mixed in specific ratios and based on the mud design desired. The equipment used in the formulation of the drilling fluid include a mixer, measuring cylinder, weighing balance used for weighing chemicals, and spatula.

Water Based Mud is usually used for less-demanding drilling of conventional vertical wells at medium depths and shallow wells. It requires less additives compared to oil based drilling mud and synthetic based drilling mud. The typical recipe for its formulation is shown in Table 2.

Table 2. Water Based Mud Formulation

ADDITIVES	FUNCTION	Unit
Fresh water	Continuous Phase	303.93 ml
Bentonite	Viscosifier	11.27 ml
Pac R	Fluidloss Agent	1.80 ml
Xanthan Gum	Fluidloss Agent	1.30 ml
NaOH	Alkalinity Source	0.01 ml
KCl	Brine source	1.69 ml
Barite	Weighting Agent	30.00g

Oil Based Mud is used for wells with greater depths or in directional or horizontal drilling, which place greater stress on the drilling apparatus [24], [25]. Table 3 shows its composition;

Table 3. Oil Based Mud Formulation

ADDITIVES	FUNCTION	Unit
Diesel	Continuous Phase	210.00 ml
Organophilic Clay	Viscosifier	25.00 ml
Emulsifier	Emulsifying Agent	20.00 ml
Gypsonite	Fluid loss Control Agent	5.00 ml
Barite	Weighting Agent	90.00 g

Mud Weight was measured using a mud balance. A mud balance consists of a volume cup with a lid on one end of a graduated beam and a counterweight on the other end. A slider-weight can be moved along the beam, and a bubble indicates when the beam is level. Density is read at the point where the slider-weight sits on the beam at level.

Rheological Property Tests

Rheology refers to the deformation and flow behavior of all forms of matter. Some rheological measurements made on fluids, such as viscosity, gel strength, etc. helps to determine how these fluids will flow under a various conditions.

The rheology test was conducted using a viscometer. For laboratory, a direct indicating rotational multi-speed instrument, has become the standard, allowing the measurements of rheological properties such as plastic viscosity, apparent viscosity, yield point, and gel strength [17]. In this study, the test procedures followed the recommended practice of standard procedure for field testing drilling fluid [15], under laboratory conditions ambient temperature of 80°F, to determine its effectiveness before being exposed to higher temperatures of 120°F, 140°F, and 160°F while making the following assumptions:
(1) Minimum or no increase in mud weight
(2) Minimum or no entrance of formation solids into the active system.
The plastic and apparent viscosities have been obtained using the basic mathematical relationships given as Equations (1) and (2), while yield point presented as indicated with Equation (3);

Plastic viscosity (PV) = 600 reading -300 reading (1)

Apparent Viscosity (AV) $=\frac{PV}{2}$ (2)

Yield Point (YP) = 300 reading – plastic viscosity (3)

Model fitting, validation and adequacy testing

Modelling of PV, YP and Gel Strength was performed by

1) Applying the polynomial equation of the form: Y = a0 + a1t + a2t2 + a3t3 for plastic viscosity, Yield point and Gel strength, at temperature t.

(2) Averaging the PV, YP and Gel strength of each mud sample by SG and Temperature and modelled an equation for each of the rheological properties using the Least Square Method.

(3) Employig the GRG (Generalized Reduced Gradient) Non-Linear Forward derivative solverin Microsoft Excel to Minimize the Difference Between Values obtained for model and measured data to better fit the model.

For each Mud sample, the rheological properties at various temperatures were recorded and plotted against temperature in MS excel using the XY Scatter plot to see the behaviour.

For each mud sample, B1 to B5, the trend was mimicked and the best trend was the polynomial of order 2. The challenge was that we then had a different equation for every mud sample and for each rheological property.

Similar approach was followed for modeling YP and gel strength [24], [25], [26]. The focus was then directed toward generating a single model that will suit the behaviour of the PV, YP and Gel strength for all Mud samples respectively.

The average of each propert y(PV,YP and Gel strength) for each temperature ranges both for WBMs and OBMs was taken. The values gotten are needed to generate an equation that mimics the behaviour of the averaged values perfectly. The least square mathematical method was used and a polynomial of order 3 was chosen to better replicate the curves. For the least square method, the difference between the model and the averaged values obtained needed to be reduced. The GRG (GENERALIZED REDUCED GRADIENT) non-linear forward derivative solver in microsoft excel was used to minimize the difference between values obtained for model and measured data to better fit the model and finally obtained values of coefficient for our model (Polynomial of order 3).

This approach was used for PV, YP and Gel strength.

So instead of having 5 equations for WBM PV for example, one for each mud sample. Finally we made comparative plot of the old models (5 equations, one for each mud sample) with the new model gotten by least square.

III. RESULTS AND DISCUSSION

The effects of temperature on plastic viscosity, yield point and gel strength of the five formulated oil based mud and water based drilling mud were determined graphically using the calculated fluid properties gotten from the viscometer readings.

Fig.1 shows the plot of the effect of plastic viscosity on temperature. All mud samples were affected by increase in temperature from 120°F. The increase in temperature had the greatest effect on B3, while B5 had the highest resistance to temperature. B3 and B4, however, did not follow the trend of the model, showing reasonable deviations.

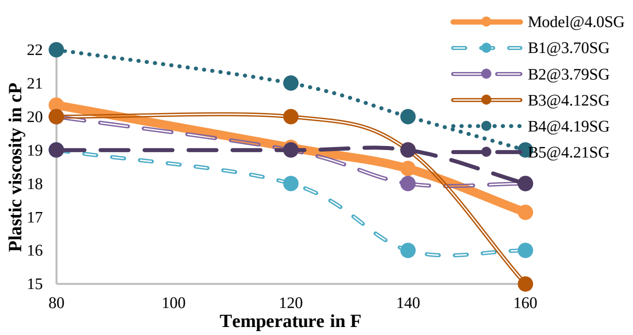

Figure 1.WBM Plastic Viscosity Model validation.

For the effect of yield point on temperature (Fig. 2), minimal effect was observed on all WBMs except for B5 and B2, but B5's YP appears to be the most sensitive to increase in temperature. Temperature also had little effect on the Model as shown by the green curve. The model actually mimicks the fuid system.

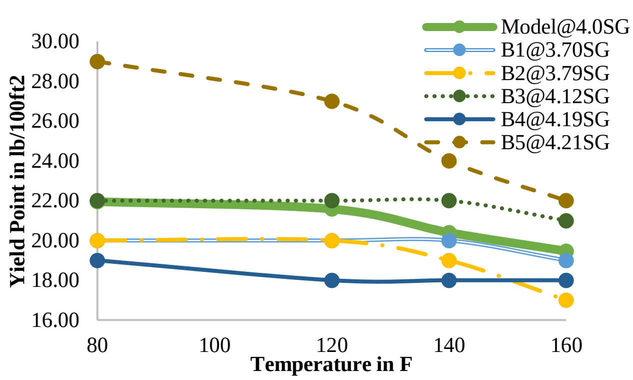

Figure 2.WBM Yield Point Model Validation

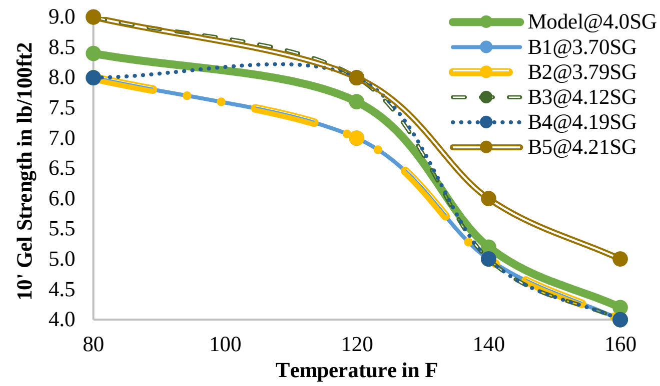

Figure 3.WBM 10' Gel strength Model Validation

It is evident from Fig. 3 that the model is a great match to all WBM 10' gel strength as all mud samples follow similar trend.

For 10" gel strength, the case is not the same. Temperature had the greatest effect on B5 10"gel strength. Temperature had so much effect on all muds generally as shown in Fig. 3. It can be seen that even WBM responded differently to temperature for the first 10 seconds but later had a reduction in gel strength in 10 minutes.

The rheology behavior for all OBMs have shown similar effect to increase in temperature from 120°F. Below 120°F, temperature had insignificant effect on the rheology of the OBMs but as the temperature increased to 120°F, PV, YP and Gel strength reduced, all tending to a common value as shown in Figs. 5, 6, 7and 8. The behaviour of OBMs YP seemed to be different when compared with PV and Gel strength. All OBMs did not follow a common trend as it did in PV and Gel strength, meaning each one will yield differently to temperature. The model was able to match all OBM rheology except YP as OBMs did not follow similar trend. But the model was able to reproduce the trend of B1. B2 and B3's YP.

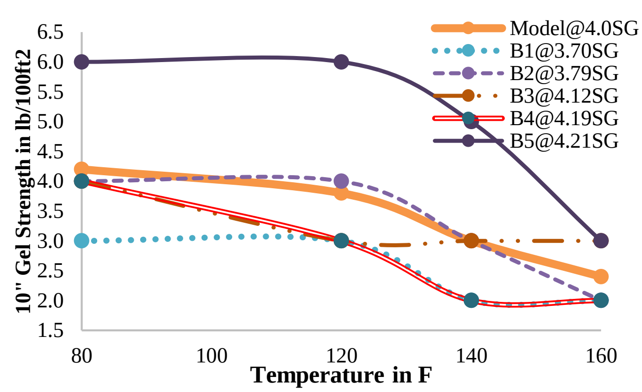

Figure 4.WBM 10" Gel strength Model Validation

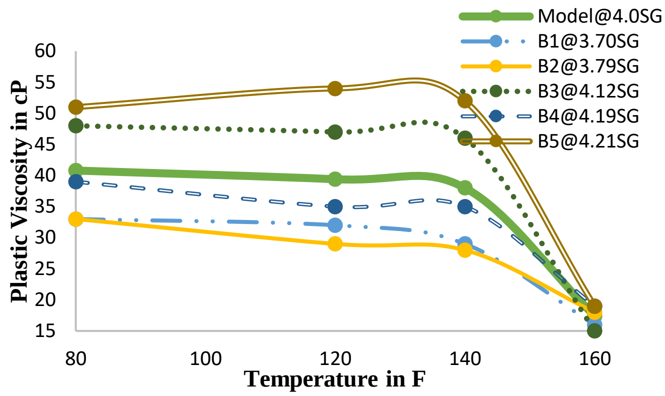

Figure 5.OBM Plastic Viscosity Model validation.

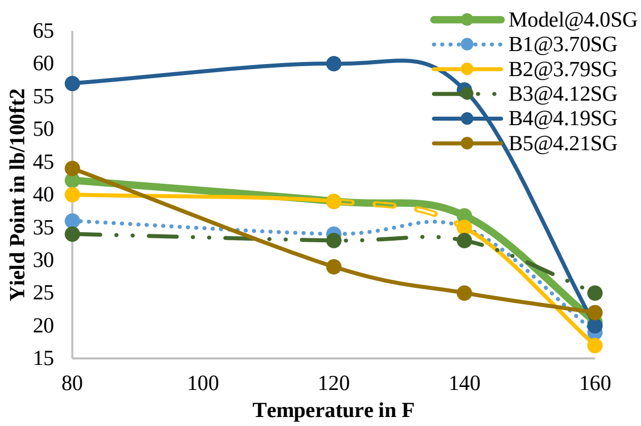

Figure 6. OBM Yield Point Model Validation

In all, the Polynomial model of order 3 matched most of the fluid behaviour to temperature changes.

For **WBM**:

$PV=SG*(-0.00000263709T^3 + 0.000897098T^2 - 0.107180009T + 9.269616982)$ was obtained for plastic viscosity.

$YP=SG*(0.000003562206T^3 - 0.00141864T^2 + 0.1731167T - 1.1058963)$ was obtained for yield point.

$G1=SG*(0.000010677083T^3 - 0.004046875T^2 + 0.479792T - 15.849)$ was obtained for 10 Minutes Gel Strength.

$G2=SG*(0.00000234375T^3 - 0.000921875T^2 + 0.110625T - 3.1)$ was obtained for 10 Seconds Gel Strength.

For **OBM**:

$PV=SG*(-0.0000732T^3+0.0247344T^2-2.7310417T +107.85)$ was obtained for plastic viscosity.

$YP= SG*(-0.0000531T^3 +0.017937T^2 -1.9925T + 82.35)$ was obtained for yield point.

$G1= SG*(-0.000036979T^3 +0.012531T^2 - 1.92083T + 54.45)$ was obtained for 10 Minutes Gel Strength.

$G2= SG*(-0.0000378T^3 +0.012671T^2 -1.393958T + 53.89)$ was obtained for 10 Seconds Gel Strength.

The new model derived mimics the behaviours of some of the mud samples for PV, YP and gel strengths.

The generated models for PV, YP and Gel strengths were validated by trying to reproduce the measured data with the generated model. The mean absolute error for each rheological property was calculated to see the percentage mean deviation of the experimental data and those generated by the model.The model adequacy data for the rheological properties considered are presented below in Tables 4 – 10.

Table 4. Model Adequacy for Plastic Viscosity

Type	Mud	Model Equations	R^2
WBM	B1	$y = -6E\text{-}05x^2 - 0.028x + 21.682$	0.8909
	B2	$y = 0.0001x^2 - 0.0541x + 23.636$	0.9471
	B3	$y = -0.0018x^2 + 0.3634x + 2.1364$	0.9738
	B4	$y = -0.0003x^2 + 0.0302x + 21.409$	0.9982
	B5	$y = -0.0004x^2 + 0.0843x + 14.773$	0.8909
OBM	B1	$y = -0.0054x^2 + 1.0943x - 20.227$	0.9693
	B2	y = -0.003x2 + 0.5484x + 8.1364	0.9373
	B3	$y = -0.0122x^2 + 2.5598x - 79.409$	0.9065
	B4	$y = -0.0052x^2 + 1.0282x - 10.273$	0.8958
	B5	$y = -0.0143x^2 + 3.0755x - 104.18$	0.9198

Table 5. Model Adequacy for Yield Point

Type	Mud	Model Equations	R^2
WBM	B1	$y = -0.0004x^2 + 0.0843x + 15.773$	0.8909
	B2	$y = -0.001x^2 + 0.1948x + 10.591$	0.9985
	B3	$y = -0.0004x^2 + 0.0843x + 17.773$	0.8909
	B4	$y = 0.0003x^2 - 0.0802x + 23.591$	0.9879
	B5	$y = -0.0007x^2 + 0.0866x + 26.864$	0.9846
OBM	B1	$y = -0.0056x^2 + 1.1625x - 21.5$	0.8582
	B2	$y = -0.0076x^2 + 1.542x - 35.318$	0.9677
	B3	$y = -0.0029x^2 + 0.5943x + 4.7727$	0.8923
	B4	$y = -0.0159x^2 + 3.3807x - 112.77$	0.9388
	B5	$y = 0.0024x^2 - 0.8459x + 96.364$	0.9995

Table 6: Model Adequacy for 10 Minutes Gel Strength

Type	Mud	Model Equations	R^2
WBM	B1	$y = -0.0005x^2 + 0.0564x + 6.4545$	0.9673
	B2	$y=0.0005x^2 + 0.0564x + 6.4545$	0.9673
	B3	$y = -0.0006x^2 + 0.0825x + 6.5$	0.9353
	B4	$y = -0.0009x^2 + 0.1627x + 0.9091$	0.8973
	B5	$y = -0.0005x^2 + 0.0564x + 7.4545$	0.9673
OBM	B1	$y = -0.0047x^2 + 0.9577x - 29.091$	0.9277
	B2	$y = -0.0043x^2 + 0.8734x - 25.864$	0.9305
	B3	$y = -0.0028x^2 + 0.5402x - 10.591$	0.9427
	B4	$y = -0.0055x^2 + 1.1264x - 35.545$	0.9231
	B5	$y = -0.0025x^2 + 0.46x - 4$	0.9441

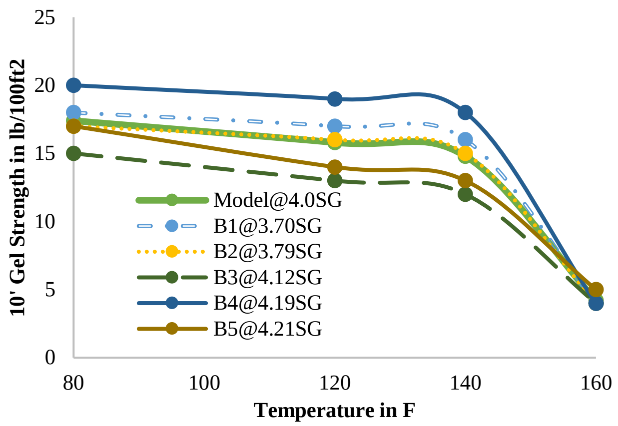

Figure 7.OBM 10' Gel strength Model Validation

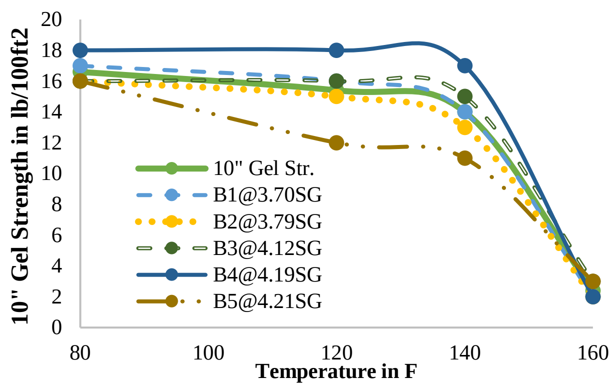

Figure 8.OBM 10" Gel strength Model Validation

Table 7. Model Adequacy for 10 Seconds Gel Strength

Type	Mud	Model Equations	R^2
WBM	B1	$y = -0.0002x^2 + 0.0261x + 2.0455$	0.7727
	B2	$y = -0.0006x^2 + 0.1105x - 1.1818$	0.9868
	B3	$y = 0.0003x^2 - 0.0802x + 8.5909$	0.9879
	B4	$y = 0.0001x^2 - 0.0541x + 7.6364$	0.9471
	B5	$y = -0.001x^2 + 0.1948x - 3.4091$	0.9985
OBM	B1	$y = -0.0048x^2 + 0.9839x - 31.045$	0.9542
	B2	$y = -0.0044x^2 + 0.8995x - 27.818$	0.9581
	B3	$y = -0.0049x^2 + 1.038x - 35.682$	0.9278
	B4	$y = -0.0061x^2 + 1.2909x - 46.364$	0.9213
	B5	$y = -0.0022x^2 + 0.3798x - 0.4091$	0.946

Table 8. Model Validation for WBM Plastic Viscosity

Data Type	SG	Fluid Type	Temperature 80°F	120°F	140°F	160°F
Measur-ed Data	3.7	B1	19	18	16	16
	3.79	B2	20	19	18	18
	4.12	B3	20	20	19	15
	4.19	B4	22	21	20	19
	4.21	B5	19	19	19	18
Model Validation	3.7	B1	18.82	17.65	17.06	15.85
	3.79	B2	19.28	18.08	17.48	16.24
	4.12	B3	20.96	19.65	18.99	17.65
	4.19	B4	21.31	19.98	19.32	17.95
	4.21	B5	21.41	20.08	19.41	18.04
Model	PV=SG*(-0.00000263709T3 + 0.000897098T2 - 0.107180009T + 9.269616982)				MAE	0.314 67%

Table 9. Model Validation for WBM 10 Minutes Gel strength

Data Type	SG	Fluid Type	Temperature 80°F	120°F	140°F	160°F
Measured Data	3.7	B1	8	7	5	4
	3.79	B2	8	7	5	4
	4.12	B3	9	8	5	4
	4.19	B4	8	8	5	4
	4.21	B5	9	8	6	5
Model Validation	3.7	B1	7.77	7.03	4.81	3.88
	3.79	B2	7.96	7.20	4.93	3.98
	4.12	B3	8.65	7.83	5.36	4.33
	4.19	B4	8.80	7.96	5.45	4.40
	4.21	B5	8.84	8.00	5.47	4.42
Model	G1=SG*(0.000010677083T3 - 0.004046875T2+ 0.479792T - 15.849)				MAE	0.3397%

Table 10: Model Validation for OBM Yield Point

Data Type	SG	Fluid Type	Temperature 80°F	120°F	140°F	160°F
Measured Data	3.7	B1	36	34	35	19
	3.79	B2	40	39	35	17
	4.12	B3	34	33	33	25
	4.19	B4	57	60	56	20
	4.21	B5	44	29	25	22
Model Validation	3.7	B1	39.04	36.07	34.04	19.05
	3.79	B2	39.98	36.95	34.87	19.52
	4.12	B3	43.47	40.17	37.90	21.22
	4.19	B4	44.20	40.85	38.55	21.58
	4.21	B5	44.42	41.05	38.73	21.68
Model	YP= SG*(-0.0000531T3 + 0.017937T2 -1.9925T + 82.35				MAE	4.443%

***MAE mean averaged error**

IV. CONCLUSIONS

It was clearly seen that the barite samples, having the highest specific gravities always had the highest mud weight in both WBMs and OBMs. Generally, the results showed that the fluid system is sensitive to temperatures. As the temperature increases from 80°F to 160°F, the rheology of the drilling fluids decreases. The effect is more significant on the yield point which is the carrying capacity of the mud than the plastic viscosity. The results have shown that increase in temperature affects both physical and chemical properties of water-based mud and oil base mud. For WBM formulation, B5 and B3 barites exhibited the best characteristics. For OBMs, B4 performed better and hence best for OBM. If B1 and B2 barites are beneficiated, they will be good for OBM formulation.

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