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**Research Article**

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# Effect of Temperature and Zinc Oxide Nanoparticle on Water-Based Mud Rheological Properties for Niger Delta Wells

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**Abstract** This work investigates the important of a Mud Engineer to carefully design and formulate a water-based mud with the right additives to drill through high pressure and high temperature formations. Therefore, it is important to establish the relationship between the formation temperature and nano water-based mud rheological properties. The mud sample was collected from Koloc48 drilling mud pit in Bayalsa State in Niger Delta and was examined at different temperature ranges ($25^0$C, $30^0$C, $35^0$C, $40^0$C, and $45^0$C) at different grams of zinc oxide powder (0g, 5g, 10g, 15g, and 20g). The equipment used were calibrated and the rheological properties of sample A (0g), sample B (5g), sample C (10g), sample D (15g) and sample E (20g) was determined at the established temperature ranges. The laboratory result show that apparent viscosity, plastic viscosity, gel-strength, density and pH decreases with increase in temperature but in contrast, the mud electrical conductivity (E.C) and yield point increased with increase in temperature. The effect of the nanoparticle (zinc oxide) examined shows that increase in nanoparticle (zinc oxide) concentration in the samples increases the apparent viscosity, plastic viscosity, gel-strength, density, E.C and pH of the mud while yield point decreased from 6.6cp to -2cp with increase in nanoparticle (zinc oxide) concentration. The results obtained is as a result of thermal degradation of the solid, polymers and other additives of the nano water-based at high temperature conditions. Therefore, with the right additives added, water-based mud will yield great success to withstand HPHT conditions.

**Keywords** HPHT Conditions, Nanoparticles, Mud Rheological Properties, Water-Based Mud

## 1. Introduction

In the early days of drilling operation, drilling was done with just a mixture of water and clay but today, drilling mud has undergone high technological and process advancement from just water and clay to complex mixture of various specific organic and inorganic products. These Complex mixtures includes additives to improve fluid rheological properties and filtration capability, allowing easy penetration of heterogeneous geological formations under ideal or high-pressure high temperature conditions [1]. An increase in formation temperature and pressure decreases the values of mud viscosity [2]. There is more concern in drilling formations with high pressure high temperature conditions, to circumvent the problem associated with such formations the right additives or nanoparticles are introduces into the mud [1]. The primary function of a mud among all, is to suspend and remove cuttings from the well, to achieve these functions, the mud is properly designed and the right nanoparticles added. HPHT wells are classified normal with bottom hole temperature (BHT) ranges of 300 – $350^0$F and 15000 psi and classified as extreme if BHT is 350 – $400^0$F and 20000 psi and lastly considered ultra when BHT is about 400 – $500^0$F and greater than or equal to 30000 psi [3]. Therefore, drilling fluids should be

designed with the right properties and additives based on the class of well drilled with respect to formation pressure and temperature else might cause drilling hazards.

## 2. Materials and Methods

The materials used in this experiment include Baroid mud balance, Marsh funnel, Speed rheometer, pH meter, Filter press, Heater, Thermometer, Conical flask, Retort stand, Tissue paper, Zinc oxide powder, water-based mud and LabPlot software.

**Table 1:** Components of water-based mud

| Additives/Components | Functions |
|---|---|
| Water | Based fluid |
| Barite | Weighting material |
| Bentonite | Viscosifier |
| Potassium Chloride | Inhibition control |
| Caustic soda | Alkalinity control |
| Barax | Preservative |
| Carboxylmethel cellulose | Thickener |
| PolyAnionic cellulose | Fluid loss control |

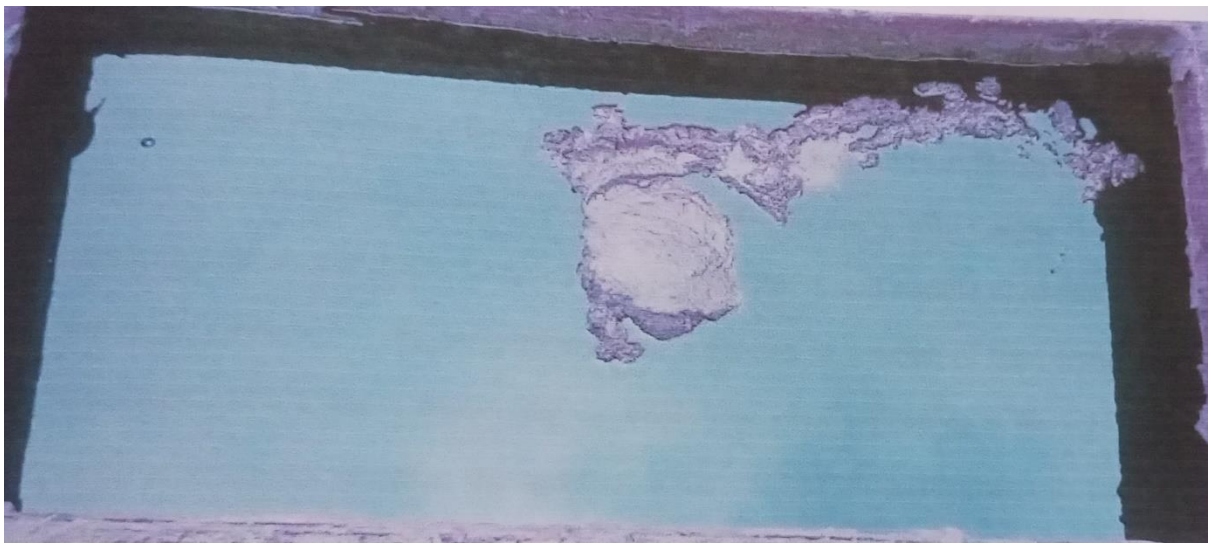

*Figure 1: Koloc48 Mud Pit (Mud Samples)*

### 2.1 Experimental Procedures

The water-based mud was divided into five equal samples in different flask labelled A to E. Where sample A is the base fluid with no zinc oxide concentration (0 gram), sample B (5 grams), sample C (10 grams), sample D (15 grams) and sample E (15 grams). The samples are then subjected to a temperature range of ($25^0$C, $30^0$C, $35^0$C, $40^0$C, $45^0$C) and finally the mud rheological properties of the samples were determined at every temperature and nanoparticle range.

## 3. Results and Discussion

The experimental results obtained from the nano water-based mud rheological test at different temperature range are presented in table 2 and 3, analysed using LabPlot software to produce the graphical relationships between the temperature, zinc oxide nanoparticle and the mud rheological properties in figure 2 and 3 respectively.

**Table 2:** Mud Rheology data showing the effect of temperature on nano water-based mud samples

| Temperature ($^0$C) | Density (ppg) | E.C (ms) | pH | Gel-strenght (1bl/100ft$^2$) | Plastic Viscosity (cp) | Yield point (cp) | Apparent Viscosity (cp) |
|---|---|---|---|---|---|---|---|
| 25 | 10.7 | 0.17 | 8.52 | 8 | 20.1 | 6.6 | 23.5 |
| 30 | 10.5 | 0.19 | 8.4 | 7.9 | 19 | 4 | 21 |
| 35 | 10.3 | 2.0 | 8.3 | 7.3 | 16 | 1 | 16.5 |
| 40 | 9.9 | 2.5 | 8.2 | 7.0 | 12 | 4 | 14 |
| 45 | 9.8 | 2.8 | 7.9 | 6.8 | 7 | 7 | 6 |

**Table 3**: Mud Rheology data showing the effect of zinc oxide nanoparticle on water-based mud samples

| Zinc Oxide (grams) | Density (ppg) | E.C (ms) | pH | Gel-strenght (1bl/100ft$^2$) | Plastic Viscosity (cp) | Yield point (cp) | Apparent Viscosity (cp) |
|---|---|---|---|---|---|---|---|
| 0 | 10.7 | 0.17 | 8.52 | 8 | 20.1 | 6.6 | 23.5 |
| 5 | 10.9 | 3.2 | 8.55 | 9 | 21 | 7 | 24.5 |
| 10 | 11.1 | 4.2 | 9.22 | 11.9 | 23 | 4 | 25 |
| 15 | 12.7 | 6.3 | 10.8 | 15 | 25 | 1 | 26.5 |
| 20 | 14 | 7.4 | 11.6 | 18 | 26 | 1 | 26.5 |

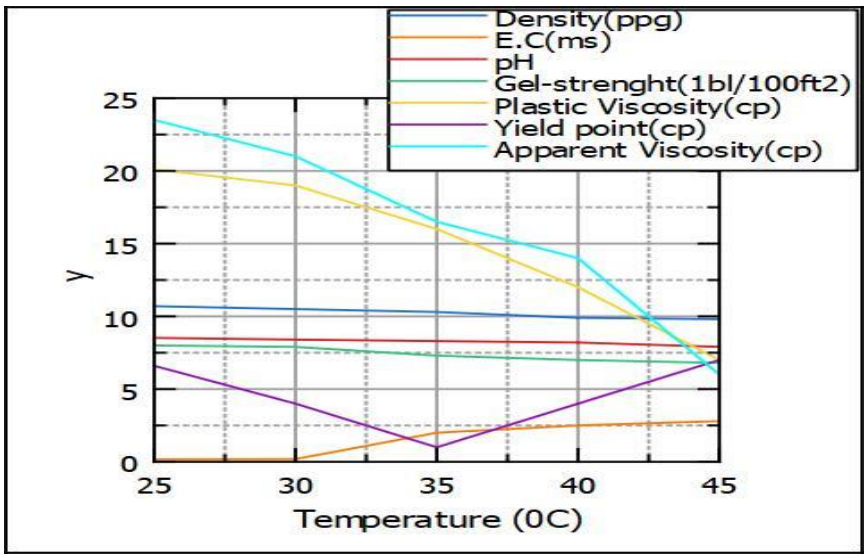


*Figure 2: Effect of Temperature on Mud Rheological Properties*

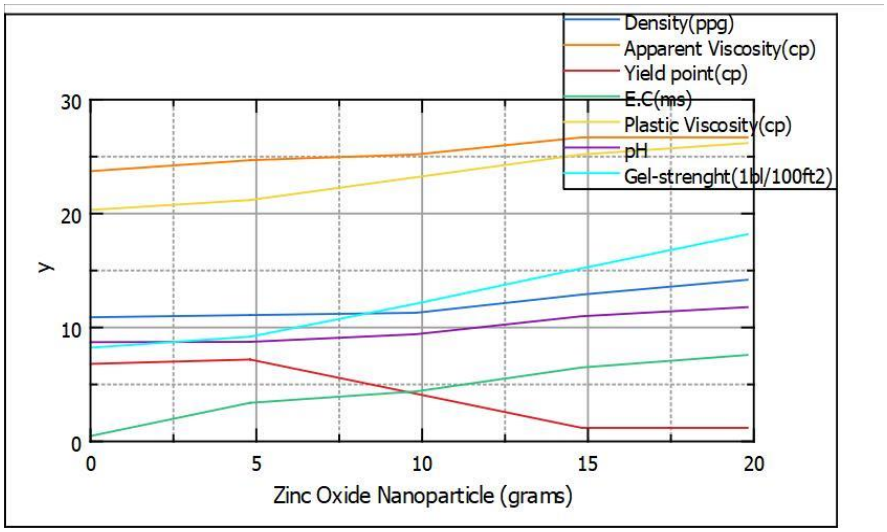


*Figure 3: Effect of Zinc Oxide Nanoparticle on Mud Rheological Properties for sample A-E.*

**4. Conclusion**

- The mud density, plastic viscosity, apparent viscosity, gel-strength and pH decreases with increase in temperature. Therefore, this mud properties should always be on check and modified at every new formation temperature encountered.
- Mud electrical conductivity increased with increase in temperature while mud gel-strength was unstable as it decreases and increases at different ranges of temperature.

The introduction of zinc oxide nanoparticle into the samples improved the rheological properties of the mud except for the mud yield point that decreased drastically as zinc oxide concentration is increased.

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