Effect of AL_2O_3 Nanoparticles on the Rheological Properties of Water Based Mud

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Abstract: This research work investigates into the performance of Aluminium Oxide nanoparticles in water based bentonite drilling fluid at high temperature formations. We looked into the thermal stability effect of the Aluminium oxide nanoparticles on the drilling fluid at varying temperature conditions. We analyzed the interactive effects of temperature, the Aluminium Oxide nanoparticles and shear rates on the shear stress of the drilling fluid. Optimization of these parameters at the high and low point of the shear stress of the drilling fluid was analyzed. We also developed a predictive expression for Shear stress as a response variable for changes in temperature, Aluminium Oxide nanoparticle and shear rate.

Keywords: Thermal stability, Optimization, nanoparticles, bentonite drilling fluid, interactive effect, shear stress

1. INTRODUCTION

Drilling fluid plays very vital role in the drilling operations of oil and gas industries. It plays a multifunctional role such as removal of cuttings, lubrication of bits, maintenance of wellbore stability and prevention of inflow and outflow of fluids between borehole and the formation. The use of water-based muds (WBMs), oil based muds (OBMs) and other synthetic based muds (SBMs) in drilling of oil and gas wells has increased considerably over the past years. New mud systems are continuously being developed and existing systems are being refined to reduce exploration costs. Now the advancement of drilling operations into high temperature formations demand the usage of drilling fluid formulae that will withstand high temperatures by stabilizing the integrity of the rheology of the drilling fluid under such conditions [9, 11] . At high temperature conditions, better thermally stable drilling fluid is required to maintain the rheological properties of this multifunctional fluid [2, 4]. Equipping drilling fluid to perform its basic functions under such conditions requires engineering the fluid with additives. Developing a stable fluid to maintain the rheological properties is an important issue at this stage [5, 8].

This study therefore explored the use of Alpha Aluminium Oxide nanoparticles as stabilizing agent under the conditions of high temperatures.

Many other studies and operation on the field have employed different types of chemicals and polymers in designing the drilling mud to meet some functional requirements such as the appropriate mud rheology, density, mud activity, fluid loss control property. Studies of nanoparticles have shown their unique abilities in their functionalities such as thermal conductivity, electrical conductivity, optical features etc. [1, 3, 6,10]. Our aim and objectives for this work are; to evaluate the effect of temperature on the drilling fluid at varying mass fractions of the Aluminium Oxide nanoparticles and different shear rates; also to evaluate the interactive effect of temperature, Aluminium Oxide nanoparticle and the Shear rate on the Shear stress of the drilling fluid; and finally to develop a prediction model that predict the effect of the nanoparticles at higher temperature formations.

2. EXPERIMENTAL PROCEDURE

2.1 Chemical Synthesis of Iron Oxide Nanoparticles

Aluminium oxide nanoparticles used was obtained from stock with the following characteristic: Spherical morphology and particle size of 40nm and crystal size of 150nm

2.2 Procedure for Bentonite Drilling Fluid Formulation

350 ml of fresh water was measured using a measuring cylinder and was added to 22.5 g of bentonite and stirred in the bucket until no more lumps were observable by the help of an electric mixer. The drilling fluid was left to stay overnight (16 hours) to swell. The formulated bentonite mud was divided to four different samples. Aluminium Oxide Nanoparticles were then added to the formulated bentonite mud samples each in the following mass fractions 0.5 g, 1 g, and 1.5 g. The sample fluids are then stirred vigorously and homogenized with an electronic mixer for about 2 minutes to ensure stable and uniform dispersion of nanoparticles in the fluid for the study.
The bentonite fluid and the treated bentonite fluids were used for the various experiments.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The viscometer analysis was completed for the aluminium oxide Np enriched drilling fluid. Analysis and discussion mainly centers on the effect on the fluid model and the thermal stability of the drilling fluids as they undergo temperature variation. Also, the statistical analysis of the parameters that affect the rheology of the drilling fluid.

3.1 Effect of Aluminum Oxide Nanoparticles on Water based Fluid Behaviour Model

Rheological properties such as yield point and plastic viscosity of the water-based drilling fluid with the presence of aluminum oxide were fairly stabilized. The behaviour can be linked to that of a Bingham plastic model as shown in figure 3-1 and 3-2 at 40 and 90 degrees Celsius temperature respectively. As we raised temperature to 90 degrees Celsius, the yield points and plastic viscosities only showed a slight variation for different mass fraction of the nanoparticles. But, the yield point for the zero nanoparticle concentration decreased as the temperature increased to 90 degrees Celsius.

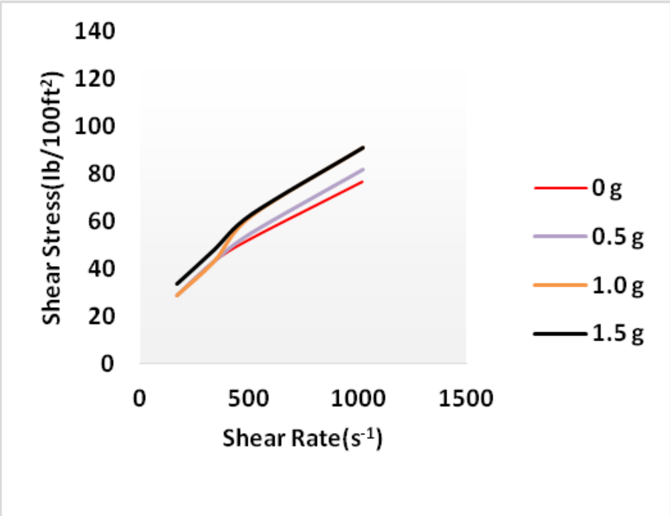

Figure 3-1: Rheogram Showing Non-Newtonian behaviour of Al_2O_3 Np Treated Water Based Mud @ 40C

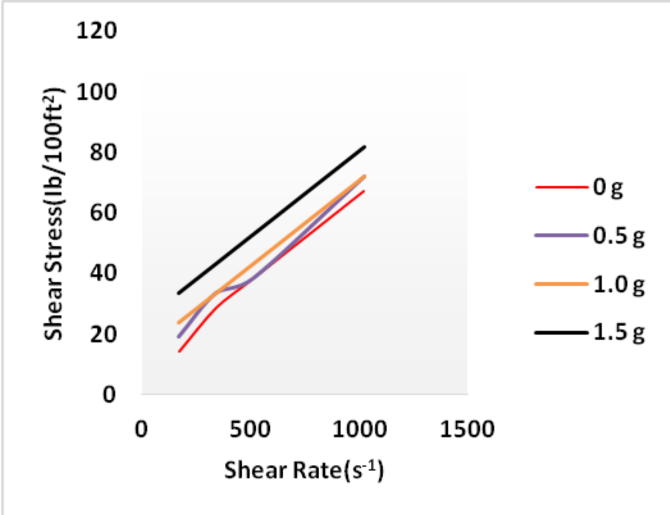

Figure 3-2: Rheogram Showing Non-Newtonian behaviour of Al_2O_3 Np Treated Water Based Mud @ 90C

3.1.1 *Thermal Effect of Aluminium Oxide on Water Based Drilling Fluid*

It can be seen clearly, especially in figure 3-3d, how the aluminium oxide Np actively maintained the rheology of the water based fluid across the temperature range. This indicates that for the same quantity of the drilling fluid, increasing the mass fraction of the nanoparticles increases the thermal stabilization of the drilling fluid

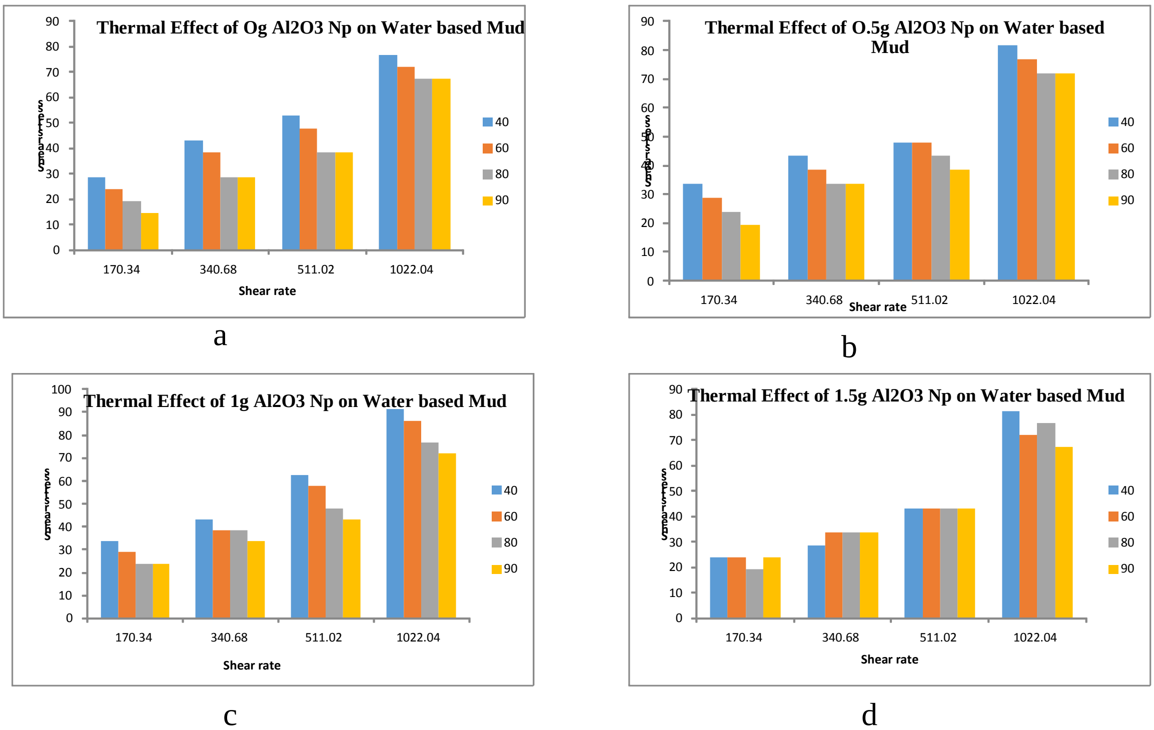

Figure 3-3: Summary of Thermal effect on Aluminium Oxide Nanoparticle treated Water Based Drilling Fluid at varying composition

3.2 Statistical Analysis

In this study we designed the experimental work using the factorial design approach[12]. This actually gave us the opportunity to analyze our results in ways that employs the multiple or combined effects of our research parameters. We used in this study the JMP software to analyze and observe the combined effects of the Aluminium Oxide nanoparticles, temperature and Shear rate on the shear stress. The following highlights the analysis of the results

Figure 3-4 below shows the actual plot of the rheology of the drilling fluid taking into consideration, the effect of Temperature and the Aluminium Oxide nanoparticles. The predictability of this experiment given by the R-square value of 0.91 indicates that the errors registered in our experiment are minimal. Therefore, the prediction model developed from this study can be used to project the effect of the nanoparticles at higher temperature regimes.

Equation 3-1 given below is our predictive factorial model or equation from the experiment.

$$S_S = 24 - 0.17T + 9.16K + 0.055B + (T - 67.5)[(K - 0.75) \times 0.036] + (T - 67.5)[(B - 511.02) \times 0.00018] + (K - 0.75)[(B - 511.02) \times 0.0057] \quad (1)$$

Where;

T= Temperature, ^{O}C

A= Shear rate, s^{-1}

k= Al_2O_3 Np, g

S_{ST}= Shear Stress, Ib/100 ft^2

Figure 3.5 is the cube plot which gives a model of how the Aluminium Oxide nanoparticles, the temperature and the sheat rate interplay at the various optimized points of the shear stress.

From this plot, it means that at the shear stress of 86.3 Ib/100ft^2, within a temperature zone of about 40 ^{o}C, a 1.5 mass fraction of the Aluminium Oxide nanoparticle must be uniformly dispersed in the drilling fluid and drilling operation set at the shear rate around1022 per second. On the other hand, minimum or no nanoparticles presence and the 90 ^{o}C temperature are required to obtain the least shear stress of 17.24 Ib/100ft^2 according to the optimization model.

The contour plot gives the performance of the Shear stress as the parameters change as in whether they increase or reduce in measure.

Figure 3-6 indicates that the Shear stress increases as Aluminium Oxide nanoparticles increases and temperature reduces.

Figure 3-7 indicates that the Shear stress increases as Shear rate increases and temperature decreases. And figure 3-8 shows that Shear Stress increases as Iron Oxide nanoparticles increases and Shear rate decreases.

Figure 3-9 is gives the interaction profile for all the parameters.

Table 3-1 shows the measured effect of the parameters on the Shear stress of the drilling fluid. The individual effects as well as the combined effect are shown. The Aluminium Oxide nanoparticles gave the highest impact which implies positive performance in stabilizing the temperature. All the combine parameters gave a negative impact on the shear stress.

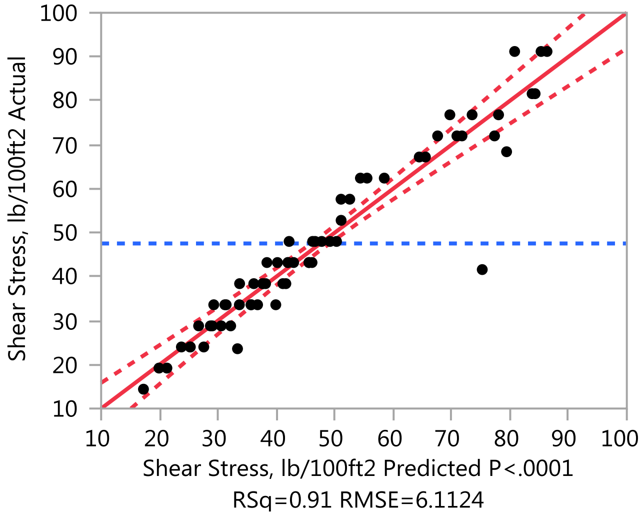

Figure 3-4: Actual by predicted plot for Shear Stress

Table 3-1: Estimated Parameters

Term	Estimate	Standard Error
Shear Rate, 1/s	**0.0554563**	**0.002398**
Al2O3 NP, g	**9.16**	**1.366763**
Temp, oC	**- 0.174661**	**0.039788**
(Temp, oC-67.5)*(Shear Rate, 1/s-511.02)	**0.0001895**	**0.000125**
(Al2O3 NP, g-0.75)*(Shear Rate, 1/s-511.02)	**0.0057029**	**0.004289**
(Temp, oC-67.5)*(Al2O3 NP, g-0.75)	**0.0357966**	**0.071175**

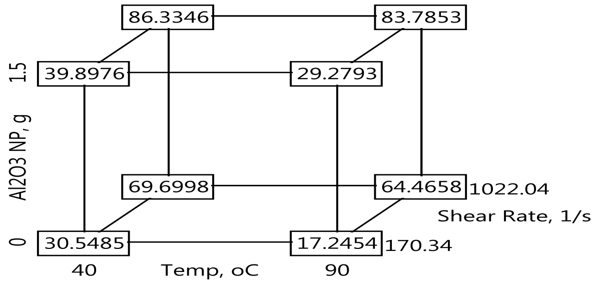

Figure 3-5: Cube plot showing optimum parameters

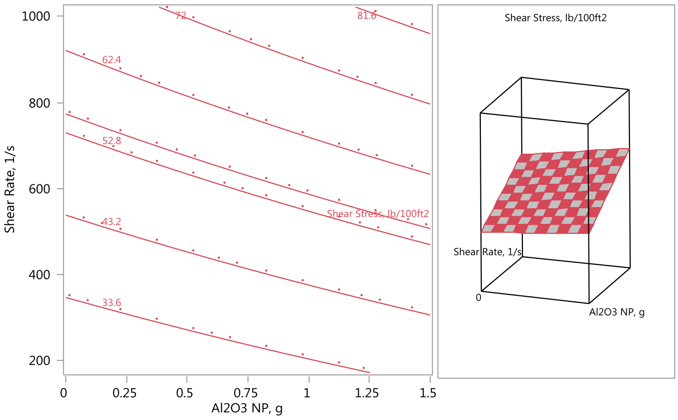

Figure 3-8: Contour Plot: Effects of Al_2O_3Np/ Shear Rate on Shear stress

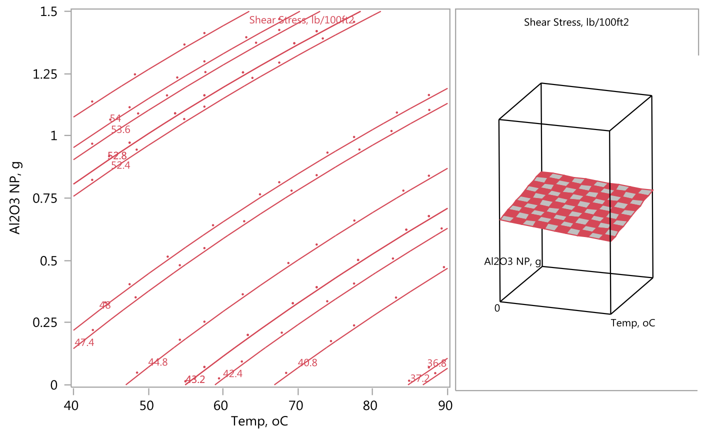

Figure 3-6: Contour Plot: Effects of Temperature/ Shear Rate on Shear stress

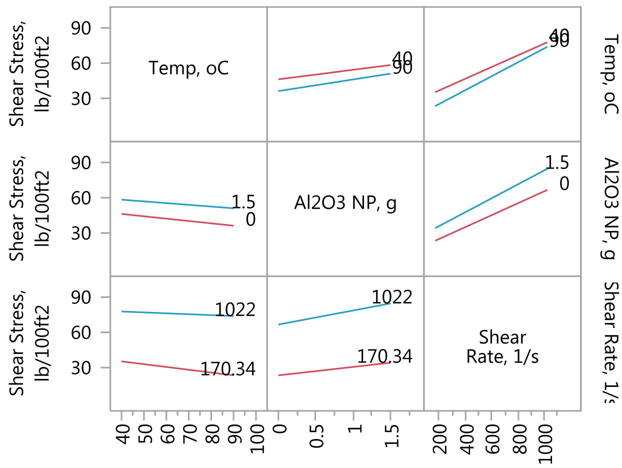

Figure 3-9: Parameters Interaction Profiles

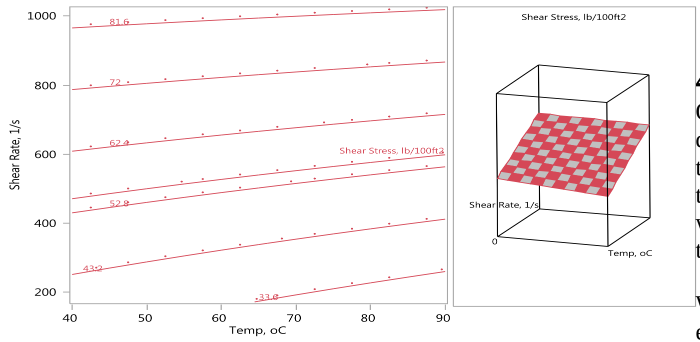

Figure 3-7: Contour Plot: Effects of Temperature/ Al_2O_3 Np on Shear stress

4. CONCLUSION

Our study has shown that Aluminium Oxide nanoparticles dispersed in the water based bentonite drilling fluid provide thermal stabilization cover for the drilling fluid under the high temperature conditions. The Aluminium Oxide nanoparticles were able to maintain the shear stresses of the fluid as temperature increases at defined levels of shear rate.

We developed a predictive model to make engineering estimates of Aluminium Oxide nanoparticles mass fractions and Shear rates when drilling operations must be made at higher temperature zones above hundred degrees Celsius was generated for this study.

In this study we also showed the Interactive effects of the Aluminium Oxide nanoparticles, temperature and Shear rate and finally the cube plot that shows the optimization levels for all the parameters at the high and low levels of the Shear stress of the drilling fluid.

Nomenclature

Np= Nanoparticles

5. ACKNOWLEDGEMENT
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