Proceedings of
The 5th Sriwijaya International Seminar on Energy and Environmental Science & Technology
Palembang, Indonesia
September 10-11, 2014

Improve Performance of Water-based Drilling Fluids Using Nanoparticles

Abdul Razak Ismail[1*], Tan Chee Seong[1], Nor Aziah Buang[2] and Wan Rosli Wan Sulaiman[1]

[1]Petroleum Engineering Department,
Faculty of Petroleum and Renewable Energy Engineering,
Universiti Teknologi Malaysia,
81300 Johor Bahru, Johor, Malaysia.

[2]Department of Chemistry, Faculty of Science
Universiti Teknologi Malaysia,
81310 Johor Bahru, Johor, Malaysia.

*Corresponding Author : razak@utm.my

.

ABSTRACT

The significant of exploring deep wells is increasing rapidly to fulfill the global oil and gas demand. Deepwater drilling in offshore operations found negative impact on the drilling fluids rheological properties when exposed to high pressure high temperature conditions. Hence, designing drilling fluids for drilling in these type of wells are the major challenges. In this study, the impact of multi-walled carbon nanotube (MWCNT) and nano metal oxides (titanium oxide, aluminum oxide and copper oxide) on the rheological properties of water based drilling fluid were investigated. The influence of different concentrations of nanoparticles on the rheological properties of water-based drilling fluid was investigated at room and elevated temperatures. The experimental results showed that the filtrate loss of the water-based drilling fluid is reduced around 65% and mud cake thickness is reduced about 30% in the presence of 1 g of MWCNT. Water-based drilling fluid with metal oxide also produced low filtrate loss. For example, water-based drilling fluid plus titanium oxide achieved more than 50% reduction in fluid loss and the filter cake thickness reduced to about 30%. Furthermore, significant improvements are seen in the rheological properties such as yield point, plastic viscosity and gel strength of the water-based drilling fluid with the presence of metal oxide and MWCNT. Overall, the application of nanoparticles on the rheological properties of water-based drilling fluid delivers on great benefits.

Keyword: nanoparticles, drilling fluid, rheological properties

1. INTRODUCTION

The success of drilling oil and gas wells are highly depending on the drilling fluid used during drilling and completion. The choice of the drilling fluid and its additives becomes more complex especially when more products of different functions are introduced from time to time. However, the need for new solution or formulation become more urgent especially the exploration of hydrocarbon moves into geological complex formation. Nowadays, number of exploration in deep wells is increasing rapidly to meet the escalating global demand on oil and gas. Drilling operations face great technical challenges with drilling problem especially in deep water operation. Drilling in deep wells will have negative impact on drilling fluids rheological properties when exposed to high pressure high temperature (HPHT) conditions.

One of the challenges related with drilling deep wells is to maintain desirable rheological

properties of the drilling fluid. Many factors in deep drilling that can be highly influenced and altered the rheological performance of drilling fluids. Research on the effect of HPHT on viscosity of both oil-based drilling fluid and water-based drilling fluid was studied [1,2]. The results showed that alteration and changes happened in the fluid rheological properties included negative impact on rheological properties of drilling fluids. Oil-based drilling fluids are preferred for HPHT condition because of their better stability and can maintain the rheological properties in such extreme condition.

However, at HTHP conditions, the drilling fluids are also likely to experience gelation, degradation of weighting materials and the breakdown of polymeric additives which act as viscosifiers, surfactants and fluid-loss additives [3,4].

Furthermore, most of the muds contain the solid particles that can cause formation damage due to poor quality of filter cake. Cutting generated while drilling may produce enough micro-sized and colloidal particles to cause severe formation damage if a poor quality filter cake is deposited on the wellbore wall. Damage by solids particles invasion and difficulties in cleaning the damage have been recognized by oil and gas industry thus, prevention of formation damage should be priority rather than clear the damage [5].

Another drilling problem is filtrate loss which occurs in the high permeability formation where the drilling fluid filters through the wall of the wellbore and invades the formation. The solid residue of the drilling fluid will deposit a layer of mud cake on the wall of the borehole. In high permeability formation, the high pressure difference caused by the drilling fluid invasion into the formation can cause the drill pipe to get stuck into the thick mud cake.

This phenomenon is called differential sticking. In field practice, a several type of fluid loss agent has been utilized in drilling fluid to reduce the drilling fluid loss. It is often impossible to reduce fluid loss with micro and macro type fluid loss additives due to physio-chemical and mechanical characteristics. Normal fluid loss additives with diameter in the range of 0.1 – 100 µm are not effective in reducing fluid loss in the formation with pore size less than 0.1 µm such as shale [6].

Both technical and environmental challenges greatly escalate the cost of drilling a well. However, oil industry views this as an opportunity to develop a cost effective and environmental sustainable drilling fluid that meet the technical requirement. As a result, nanotechnology comes into interest of oil and gas industry as a candidate that offer the solution for the above challenges due to its special character. The objective of this research was to use nano metal oxide and multi-walled carbon nanotube in drilling fluids to improve the rheological performance at HTHP drilling conditions.

2. METHODS

Water based drilling fluid is formulated using MWCNT and nano metal oxide including titanium oxide (TiO_2), aluminum oxide (Al_2O_3) and copper oxide (CuO). In this procedure, purified MWCNT was added to 50 ml of surfactant solution with concentration of 1% by weight. The dispersion was ultra-sonicated for 4 hours to obtain the well-dispersed MWCNT. However, metal oxides were added to 50 ml of distilled water, and then ultra-sonicated for 4 hours to break the agglomerates.

Before adding nanoparticles, rheological properties of water based drilling fluid sample was tested. The concentration of nanoparticles that was used in formulating drilling fluid samples is 0.001 g, 0.01 g, 0.1 g and 1 g. Well-dispersed functionalized MWCNT by using surfactant treatment is used for water based drilling fluid; however pure MWCNT is for synthetic based drilling fluid. Meanwhile, metal oxides dispersed in distilled water are used for water based drilling fluid.

Each nano-based drilling fluid was prepared and tested. Basic rheological properties were carried out such as mud weight, plastic viscosity, yield point, gel strength, filter cake thickness and filtrate loss at HTHP. The drilling fluid samples were tested at room temperature and aging for 250°F and 16 hours.

3. RESULTS

Effect of Different Types of Nanoparticles and Concentration on Rheological Properties

Plastic Viscosity

The result shows that the plastic viscosity of water based drilling fluid reduces after exposed

to 250°F. Figure 1 shows that the trend of copper oxide decreases when the concentration increases. However, the plastic viscosity of water based drilling fluid with titanium oxide; aluminum oxide and MWCNT were found slightly higher than controlled sample without nanoparticle.

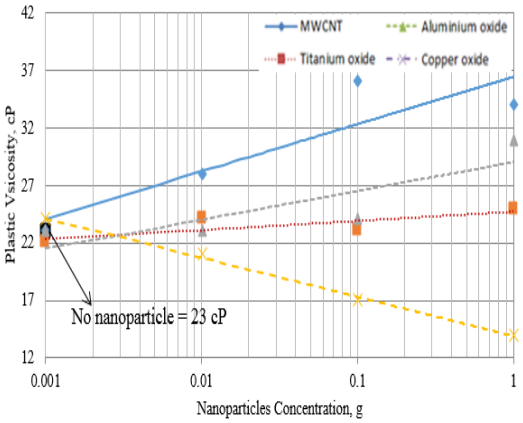

Fig. 1. Effect of Nanoparticle Concentration on Plastic Viscosity

Nanoparticles consist of large surface areas per volume and it will increase the interaction of the nanoparticles with the matrix and surrounding water-based drilling fluid.

This surface area may serve as sites for bonding with functional groups can influence chain entanglement and thus can generate a variety of properties in the matrix. Thus, the nanoparticles and base fluid may be linked or bonded together directly or through certain intermediate chemical linkages to improve the plastic viscosity of water based drilling fluid [7].

However, repulsive force occur between copper oxide nanoparticle and water molecular, thus is caused the plastic viscosity reduce as concentration increase due to greater repulsive force occur. In drilling fluid, it will maintain viscosity of drilling fluid at high pressure and high temperature [8].

Then, the rheological behavior may depend on the particle type, size, concentration and inter-particle distance of nanoparticles with the fluid because of the large surface area of nanoparticles compared to micron-sized and larger particles.

For example only about 1 lb/gal of nanoparticles may do the job of 10 lb/gal of other materials. The reduced solid volumes with increased surface area would thus help maintain equivalent viscosities of drilling fluids [7].

Yield Point

Figure 2 shows the effect of nanoparticle concentration on yield point in water-based drilling fluid. The yield point of MWCNT and aluminum oxide increases as nanoparticle concentration increases.

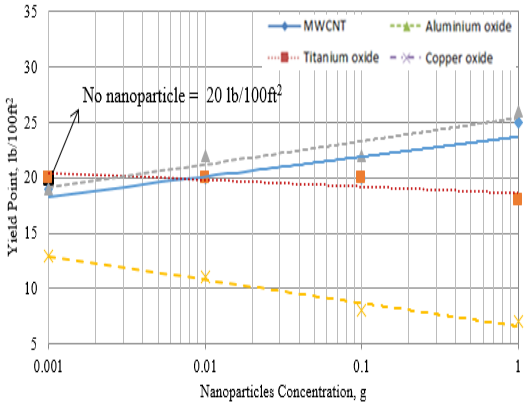

Fig. 2. Effect of Nanoparticle Concentration on Yield Point

The higher yield point of the nano-based fluid will provide better dynamic suspension of drilling cuttings and efficient cleaning of the wellbore while drilling.

However, the value of yield point was decreased when the nanoparticle concentration increased for both titanium oxide and copper oxide.

Gel strength

Figures 3 and 4 show the effect of nanoparticles on gel strength at different concentrations at 10 second and 10 minutes respectively. Both MWCNT and aluminum oxide shows an increasing trend as concentration increased.

This phenomenon occurs due to the electrostatic force between the nanoparticles that the attractive force causes the nanoparticles link together with base fluid within 10 sec and 10 min period to form a rigid structure, thus it will increase the gelling effect.

This trend, however, was not followed by other nano-based drilling fluid samples where gel strength was found to reduce gradually as concentration increased.

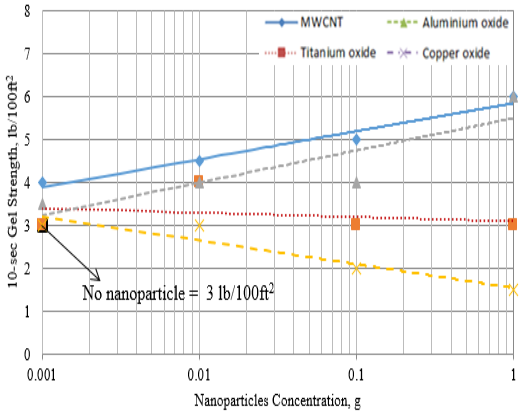

Fig. 3. Effect of Nanoparticle Concentration on Gel-Strength (10-sec)

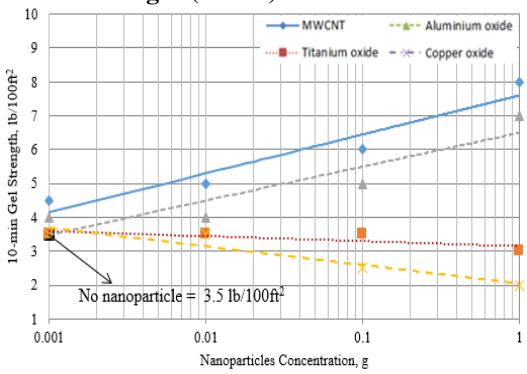

Fig. 4. Effect of Nanoparticle Concentration on Gel-Strength (10-min)

This is due to the repulsive force happened between the nanoparticle and base fluid which cause the expansion between nanoparticle and water molecule, thus it will reduce the gel strength.

HPHT Filtration Loss

The comparison of the HPHT fluid loss behavior of the water base drilling fluid with different concentration of nanoparticles is illustrated in Figure 5.

An increased in nanoparticle concentration for MWCNT give lower filtration loss that shows a very good result. The dispersed MWCNT acted as plaster between the particles and seal the permeable filter cake at high temperature to reduce the fluid loss [9].

The addition of metal oxide nanoparticles (titanium oxide, aluminum oxide and copper oxide) is only good until 0.01 g and then increases after that value.

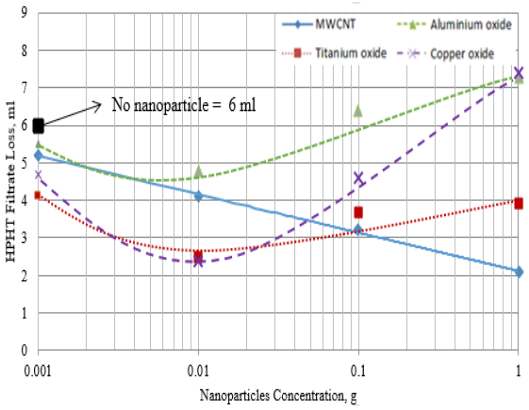

Fig. 5. Effect of Nanoparticle Concentration on HPHT Filtration Loss

Filtrate loss must be low enough to prevent excessive filter cake thickness and reduce the change of different pressure sticking.

Filter Cake Thickness

Figure 6 illustrated the result of filter cake thickness of four different types of nano-based water-based drilling fluid against the different concentration of nanoparticles.

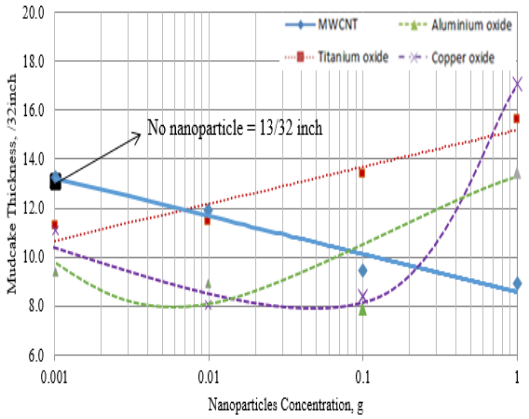

Fig. 6. Effect of Nanoparticle Concentration on Filter Cake Thickness

MWCNT showed a decreasing trend where the filter cake thickness decreases when the concentration of MWCNT increases. On the contrary, the trend of titanium oxide is increases as concentration of nanoparticle increases and this phenomenon is not good.

However, copper oxide and aluminum oxide showed similar trend where they reached the optimum value of 0.1 g and then increased sharply as the concentration increases.

4. CONCLUSION

Based on this experimental study, several conculsions can be derived:

1. An increase concentration in MWCNT and aluminum oxide resulted in higher plastic viscosity, yield point and gel strength for water base drilling fluid. On the contrary, however, titanium oxide and copper oxide resulted in decrease plastic viscosity, yield point and gel strength.
2. An addition of nanoparticles into water base drilling fluid at HPHT give better results because the fluid loss and the filter cake thickness were reduced. This is due to the large surface area to volume ratio of nanoparticles to build structural barriers to the pore spaces to block and seal the porous media.
3. Overall results show that nanoparticles can be added to water based drilling to enhance the properties of drilling fluids.

ACKNOWLEDGMENTS

The authors wish to thank Ministry of Education under Fundamental Research Grant Scheme (Vot FRGS/1/2014/TK06/UTM/02/12) and Universiti Teknologi Malaysia for funding this project and Scomi Oiltools for providing the chemicals and additives.

REFERENCES

[1] M. Amani, and M. J. Al-jubouri, “An Experimental Investigation of the Effects of Ultra High Pressures and Temperatures on the Rheological Properties of Water-Based Drilling Fluids”, SPE/APPEA International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 Sept. 2012

[2] Y. Jung, M. Barry, J. K. Lee, P. Tran, Y. Soong, D. Martello, and M. Chyu, "Effect of Nanoparticle-Additives on the Rheological Properties of Clay-Based Fluids at High Temperature and High Pressure", AADE National Technical Conference and Exhibition, Huston, Texas, 12 - 14 Apr. 2011

[3] D. J. Oakley, K. Morton, A. Eunson, A. Gilmour, D. Pritchard, and A. Valentine, "Innovative Drilling Fluid Design and Rigorous Pre-Well Planning Enable Success in an Extreme HTHP Well", IADC/SPE Asia Pacific Drilling Technology Conference, Kuala Lumpur, Malaysia. 11 - 13 Sept. 2000.

[4] S. Shah, and M. Fakoya, "Rheological Properties of Surfactant-Based and Polymeric Nano-Fluids", SPE/ICoTA Coiled Tubing & Well Intervention Conference & Exhibition, Woodlands, TX, USA. 26 - 27 Mar. 2013

[5] M. Amanullah, M. AlArfaj, and Z. Al-Abdullatif, "Preliminary Test Results of Nano-Based Drilling Fluids for Oil and Gas Field Application", SPE/IADC Drilling Conference and Exhibition, Amsterdam, Netherland, 1 - 3 Mar. 2011

[6] M. Amanullah, and A. M. Al-Tahini, "Nano-Technology - Its Significance in Smart Fluid Development for Oil and Gas Field Application", SPE Saudi Arabia Section Technical Symposium, AlKhobar, Saudi Arabia, 9 – 11 May 2009.

[7] L. Quintero, A. E. Cardenas, and , D. E. Clark, "Nanofluids and Methods of Use for Drilling and Completion Fluids", US Patent 2012/0015852 A1, 19 Jan. 2012.

[8] M. M. Husein, M. F. Zakaria, and G. Hareland, "Novel Nanoparticle-Containing Drilling Fluids to Mitigate Fluid Loss", Google Patent WO2013116920A1, 15 Aug. 2013.

[9] J.E. Park, G.R. Kim, D.J. Yoon, C.H. Sin, I.S. Park, T.S. Bea, and M.H. Lee, "The Effect of Dispersed MWCNTs Using SDBS Surfactant on Bacterial Growth", World Academy of Science, Engineering and Technology, Vol. 6, pp. 697 – 700, 28 Oct. 2012.