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Application of nanomaterials to enhanced the lubricity and rheological properties of water based drilling fluid

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Abstract. The ever-growing demand of petroleum resources lead to depletion of easily accessible reservoirs. To meet the petroleum demands, exploration of challenging reservoirs must be taken up. This can be done by drilling deviated, horizontal and deeper well with high pressure and high temperature reservoirs. However, such drilling leads to harsh drilling circumstances such as torque and drag. These circumstances can be overcome by adding appropriate amount of nanomaterials to reduce drilling problems such as pipe sticking, thermal instability, torque and drag. This paper emphasis and investigates the usage of lubrication behaviour of drilling fluids by adding multi-walled carbon nanotubes (MWCNT) and graphene nano-platelets (GNP) to reduce coefficient of friction of water based drilling fluid. Experiments were conducted to study the characteristics of added nanoparticles on drilling fluid, where by analysing the rheological properties, filtrate loss fluid and lubricity. The results showed that the addition of MWCNT at 0.01 ppb and 0.02 ppb of GNP gave torque lubricity reduction between 38 to 59%. The comprehensive nanomaterial behaviour in water based drilling fluid favoured the enhancement of drilling fluid lubricity and marginally improved the drilling fluid rheological properties such as plastic viscosity, yield point and filtrate loss of drilling fluid.

1. Introduction

During extended and horizontal well drilling, one of the prime factors that limits the well length is the torque and drag between the drill string and wellbore. As a results, it decreases the drainage efficiency of oil reservoirs. Hook load increase during tripping due to high friction which leads to reduction in the equipment life and essentially decrease in the well length. There are several innovative drilling fluid systems that have been applied to combat these problems in completion and drilling engineering. One of such innovative drilling fluid system is obtained by adding appropriate amount of suitable nanomaterials in to the drilling fluid [1].

One of the major component of these torque and drag problems is the friction between the drill string and the borehole wall. Drilling fluid plays significant role in reducing the torque and drag problems. Micro and macro material-based drilling fluids have limited capability to reduce this torque and drag problems. Due to fine and very thin film forming capability of nanomaterial's, nano-based fluids can provide a significant reduction of the frictional resistance between the pipe and the borehole wall due to the formation of a continuous and thin lubricating film in the wall-pipe interface. Moreover, the tiny spherical nanoparticles may create an ultra-thin bed of ball bearing type surface between the pipe and the borehole wall and thus can allow easy sliding of the drill string along the nano-based ball-bearing

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surface. This highlights the extraordinary role of nano-based smart fluid in reducing the torque and drags problems of horizontal, extended reach, multilateral and coiled tubing drilling [2].

The use of nanotechnology as an additive in drilling fluids has been investigated for several years resulting in mixed success. The necessity to either solve drilling problems or develop products that perform more efficiently has motivated fluids researchers to look towards nanotechnology and see what benefits it may bring in the area of rheology, fluid loss, reduction of coefficient of friction or improve lubricity of drilling fluids [3]. Recent works on addition of nano-additives in drilling fluid have proven increase in drilling fluid lubricity and improved rheological properties of water based drilling fluid and had been field trial successfully [4]. Taha *et al.* reported a reduction up to 80% in torque and an increase of 40 - 60% in rheological properties [4]. This graphene enhanced product provides superior lubricity and thermal stability to the water based drilling fluids will penetrate into microscopic pores of the tubular metal, crystalized in layers under high pressure, forming a protective film to improve lubricity, prevent bit balling, improve BHA's life span, improve ROP, and most important of all improving fluids' thermal stability.

The aims of this study are to compare and evaluate the coefficient of friction of the water based drilling fluid performance by adding multi-walled carbon nanotubes and graphene nano-platelets.

2. Methodology

Water based drilling fluid was prepared based on the composition shown in Table 1. The drilling fluid was weighed to achieve the density of about 13 lb/gal. MWCNT and graphene nano-platelets were added as additives at various concentration (0.01 - 0.04%). Tween-80 and distilled water were used to disperse the nano-materials to make sure that it will be uniform in the water based drilling fluid. All tests for drilling fluids were conducted according to standard test of API Recommended Practice 13B. The tests were conducted before hot rolled (BHR) and after hot rolled (AHR) at 250 ^{o}F for 16 hours.

Table 1. Composition of water based drilling fluid.

Material	Function
Distilled water	Based fluid
Potassium chloride (KCl)	Shale inhibitor
Caustic Soda (NaOH)	Alkalinity control agent
Flowzan	Viscosifier
Hydro-PAC UL	Filtrate control agents
Hydro-CAP XP (PHPA)	Retards dispersion of drill cuttings
Barite	Weighting agent

3. Results and discussion

Rheological properties play an important role in drilling fluid formulation. Addition of various concentration of nanomaterials show some improvements in the drilling fluid rheological properties as discussed below.

3.1. Plastic viscosity

The values of plastic viscosity without the addition of nano-materials, before and after hot rolled are 24 cP and 21 cP respectively. As shown in the Figures 1 and 2 for both nanomaterials, the trend shows marginal increment of plastic viscosity, but decrement upon adding various concentrations of GNP before hot rolled. MWCNT gives the higher values of plastic viscosity compared to GNP after hot rolled, mostly at 0.02% concentration. 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 [5].

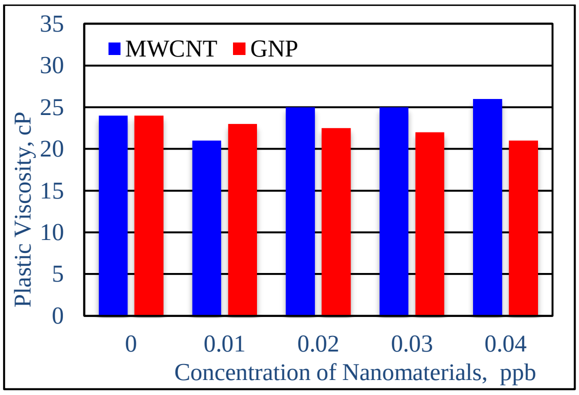

Figure 1. Plastic viscosity at different concentration of nanomaterials – before hot rolled.

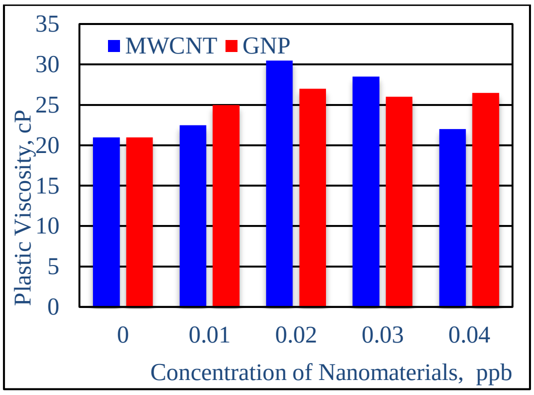

Figure 2. Plastic viscosity at different concentration of nanomaterials – after hot rolled.

3.2. Yield point

Figure 3 shows the effect of GNP and MWCNT concentration on yield point for before hot rolled. It can be seen that, yield point increases with increase in GNP concentration. Whereas, increasing the concentration of MWCNT the yield point shows unusual behaviour. After hot rolled, both the nanomaterials follow the same trend as shown in Figure 4. For MWCNT, yield point at 0.0 ppb is 32 lb/100ft^2 which increases to 36 at 0.01 and reaches maximum of 42 for 0.02 ppb. Upon further increase in concentration the yield point starts to decrease to 41 for 0.03 and 31 for 0.03.

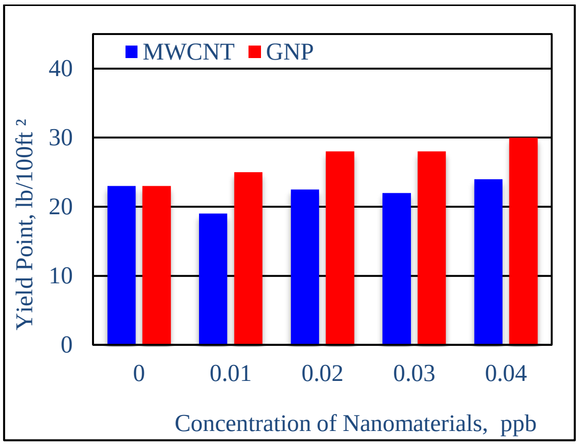

Figure 3. Yield point at different concentration of nanomaterials – before hot rolled.

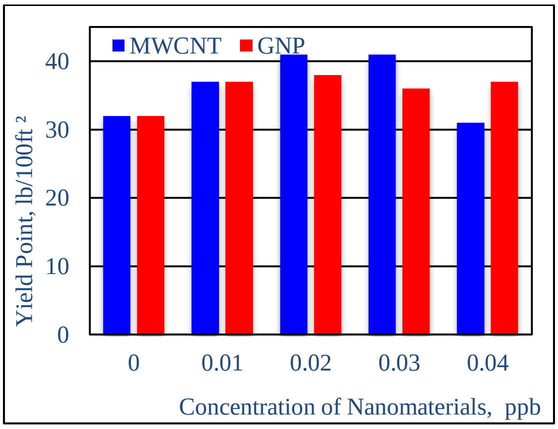

Figure 4. Yield point at different concentration of nanomaterials – after hot rolled.

3.3. Fluid loss or filtrate volume

Figures 5 to 8 showed that the fluid loss volume of MWCNT gives the lowest volume compared to GNP on both BHR and AHR, since MWCNTs have high surface area as it is hydrophobic (non-polar), which can prevent water from escaping the drilling fluid compared to GNP. In the shale formation it can prevent the swelling of shale. As per Ismail et al results showed that the filtrate loss of the water-based drilling fluid is reduced around 65% and filter cake thickness is reduced about 30% in the presence of 1 g of MWCNT [6]. These nanomaterials got attached to the drilling fluid material and formed thin and impermeable filter cake prevent fluid loss [7].

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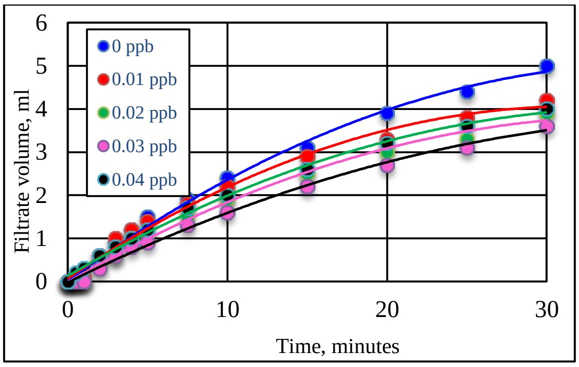

Figure 5. Fluid loss at different concentration of MWCNT – before hot rolled.

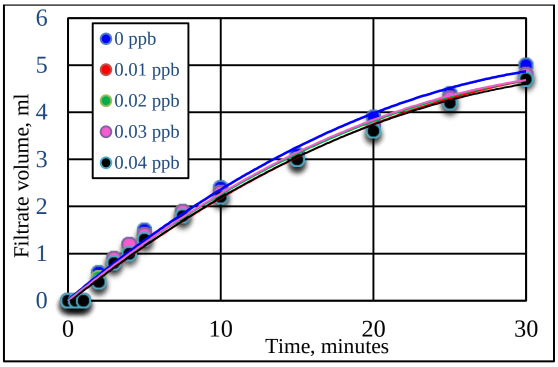

Figure 6. Fluid loss at different concentration of GNP – before hot rolled.

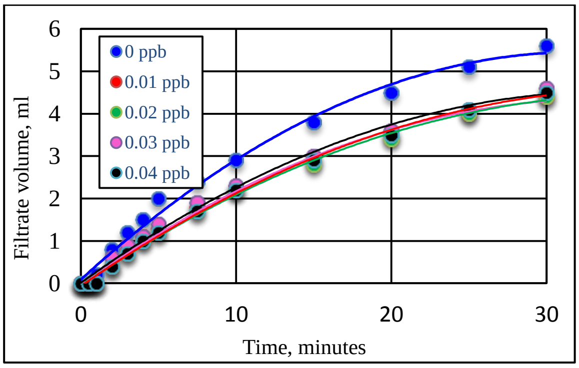

Figure 7. Fluid loss at different concentration of MWCNT – after hot rolled.

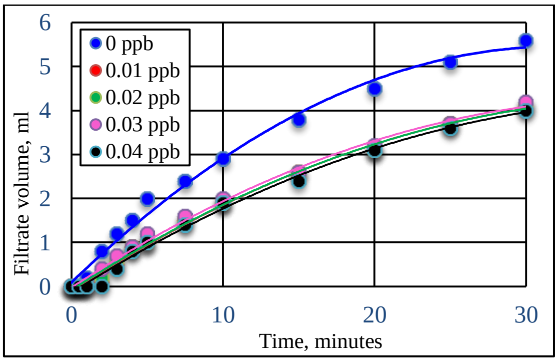

Figure 8. Fluid loss at different concentration of GNP – after hot rolled.

3.4. Lubricity

Coefficient of friction (CoF) describes the ratio of the force between two bodies and the force pressing them simultaneously. Figures 9 and 10 showed the CoF trends after addition of various concentration of nanomaterials into the drilling fluid, where MWCNT produces a reduction torque about 62% and GNP shows reduction torque of about 52% before hot rolled. GNP in water based drilling fluid at after hot rolled shoed slightly increased in CoF values that clarify the nanomaterial gives less effect to the lubricity of drilling fluid as concentration increased. Nonetheless, at concentration 0.01 ppb of MWCNT act as optimum concentration for enhance the torque reduction in WBM around 59% even at high temperature due to heat resistance capability.

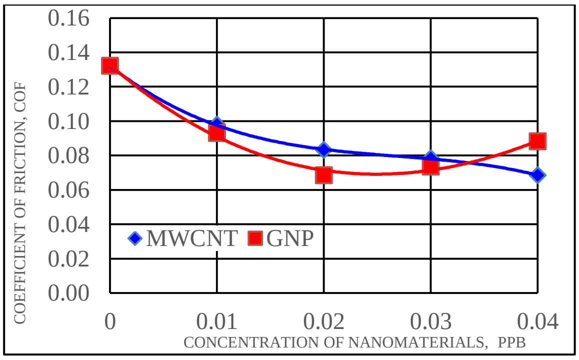

Figure 9. CoF at different concentration of nanomaterials – before hot rolled.

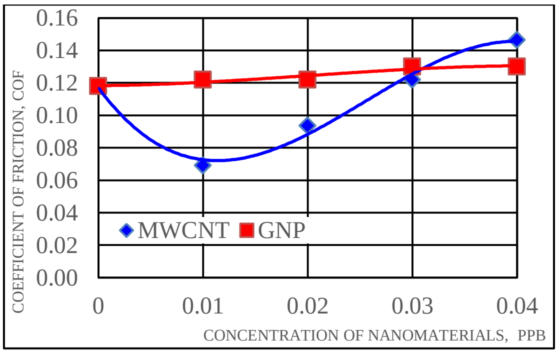

Figure 10. CoF at different concentration of nanomaterials – after hot rolled.

4. Conclusions
Based on the experimental study, several conclusions can be derived:

a) Addition of multi-walled carbon nanotubes and graphene nano-platelets in water based drilling fluid improved the rheological properties of the drilling fluid.
b) Addition of added multi-walled carbon nanotubes reduced fluid loss and promotes prevention of swelling in the shale formation.
c) Addition of a very small quantity of nanomaterials concentration resulted in drastic reduction of coefficient of friction from 38% to 59% before hot roll and the trend changed after hot roll as the nanomaterials get dispersed at high temperature.
d) Multi-walled carbon nanotubes provide better lubricity compared to graphene nano-platelets at elevated temperature.

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