Evaluation on the Presence of Nano Silver Particle in Improving a Conventional Water-based Drilling Fluid

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Abstract. Worldwide demand in oil and gas energy consumption has been driving many of oil and gas companies to explore new oil and gas resource field in an ultra-deep water environment. As deeper well is drilled, more problems and challenges are expected. The successful of drilling operation is highly dependent on properties of drilling fluids. As a way to operate drilling in challenging and extreme surroundings, nanotechnology with their unique properties is employed. Due to unique physicochemical, electrical, thermal, hydrodynamic properties and exceptional interaction potential of nanomaterials, nanoparticles are considered to be the most promising material of choice for smart fluid design for oil and gas field application. Throughout this paper, the effect of nano silver particle in improving a conventional water based drilling fluid was evaluated. Results showed that nano silver gave a significant improvement to the conventional water based drilling fluid in terms of its rheological properties and filtration test performance.

1. Introduction
The success in drilling operation in oil and gas production is highly depending on the performance of drilling fluid used. Drilling fluid is design to ensure the rotary drilling of subterranean formations is conceivable and economical with minimal negative impact to environment [1]. Drilling activities will meet great technical challenges especially in deep water operation. Under high pressure and high temperature (HPHT) conditions, performance of drilling fluid used in drilling activities could be diminished from its design parameters, hence led to technical problems such as pipe sticking, loss circulation and invasion to formation. Up to date, nanotechnology is considered as an advance technology in energy industries. The main difference between drilling fluids containing nanoparticles and the conventional base fluid is due to the very small sizes of the particles dispersed in them [2]. In this paper, nano silver was used as an additive in water based drilling fluid formulation towards enhancing the performance of the drilling fluid. The performance of the water based drilling fluid such as the changes on density, rheological properties and filtration test was evaluated.
2. Materials and Methodology

2.1. Materials
Nano silver particle was supplied by Terra Techno Engineering Company. It is in a form of powder and grey in color. Its average particle size is less than 100 nm and has a surface area of 3.7 m²g⁻¹.

2.2. Preparation of water based drilling fluid
Table 1 shows the composition that was used to prepare a water based drilling fluid [3]. The selected materials follow the ANSI/API 13A/ISO 13500 Specification for drilling fluid materials standard. Four samples of water based drilling fluid were prepared using a mixer, brand Hamilton. Every time an addition of component was made, a continuous stirring for about five minutes was conducted to make sure the added components are thoroughly mixed. Step wisely, fresh water and prehydrated gel were added, followed by soda ash, potassium chloride and caustic soda, Hydrozan and Hydro star NF®, barite and lastly nano silver particle (0.1 – 1.0 g). After the last component was added, the final mixture was stirred for one hour to confirm homogeneity, through visual observation. All tests were conducted according to ANSI/API 13B-1/ISO 10414-1 standard.

Table 1. Elements in water based drilling fluid formulation.

| Material            | Function                        | Quantity (gram) |
|---------------------|---------------------------------|-----------------|
| Fresh Water         | Base fluid                      | 287.22          |
| Prehydrated Gel     | Viscosifier                     | 22.56           |
| Soda Ash            | Hardness control                | 0.20            |
| Potassium chloride  | Water activity and cation exchange | 39.13       |
| Caustic Soda        | pH controller                   | 0.70            |
| Hydrozan            | Viscosifier                     | 1.50            |
| Hydro star NF®      | Fluid loss                      | 141.49          |
| Barite              | Weighing agent                  | 3.50            |

2.3. Drilling fluid density measurement
Density of water based drilling fluid (or mud weight) was measured using a drilling fluid balance of accuracy to within 0.01 gcm⁻³. The lid of the balance was removed from the balance cup and drilling fluid sample was placed inside the cup. The cup was covered with the lid and some drilling fluid was ensured to overflow from a hole of the lid to make sure the cup was fully filled with drilling fluid. Then, the arm balance was placed on the base, with the knife-edge resting in the fulcrum. The rider was moved along graduated arm until the vial was centered. Density measurement was recorded at the left hand edge of the rider.

2.4. Drilling fluid rheology measurement
Rheology properties of water based drilling fluid were determined by using a viscometer, brand Grace Instrument, US, model M3600 [4]. Drilling fluid sample was placed in the viscometer cup. The knurled knob was turned between the rear support posts to raise or lower the rotor sleeve until it was immersed in the sample to the scribed line. A dial reading at speed 300 RPM and 600 RPM was recorded. Plastic viscosity (PV) measurement was calculated by taking a dial reading at 600 RPM minus a dial reading at 300 RPM. A yield point (YP) measurement was calculated by subtracting PV value from the 300 RPM dial reading.

2.5 Filtration test
Filtration test was conducted at standard room temperature by using a high pressure, high temperature filter press equipment (HPHT filter press). Volume of filtrate of the sample was measured at pressure of 100 and 500 psi, after the sample was left for 30 minutes in a standard cell.

3. Results and discussion
Figure 1 shows that the presence of nano silver gave an insignificant effect on mud weight of water based drilling fluid. The mud weight of water based drilling fluid without the presence of nano silver is
9.0 ppg (i.e. pounds per gallon) as stated in ANSI/API 13A/ISO 13500 standard. Consequently, in the presence of nano silver at 0.1 g, 0.5 g and 1.0 g, the density is 9.1 ppg, 9.1 ppg and 9.3 ppg, respectively. In drilling operation, mud weight is designed slightly higher than formation pressure to ensure maximum penetration rate [5]. Too high mud weight will cause loss circulation of formation, stuck of drill pipe, decrease on penetration rate and formation damage. In general, the presence of nano silver gave ambiguous effect on mud weight due to negligible dimension of its particle size. Hence, the presence of nano silver would not affect the common drilling operation.

![Figure 1](image1.png)

**Figure 1.** Density measurement of water based drilling fluid with and without the presence of nano silver. Data shown are with 5% error bar.

Plastic viscosity (PV) is defined as a resistance of fluid to flow [6]. PV represents the viscosity of drilling fluid. Figure 2(a) shows the viscosity of water based drilling fluid with and without the presence of nano silver.

![Figure 2(a)-(b)](image2.png)

**Figure 2(a)-(b).** Plastic viscosity measurement of water based drilling fluid with and without the presence of nano silver. Data shown are with 5% error bar.

Significant increment due to the presence of nano silver as shown in figure 2(a) is reflected in figure 2(b), in terms of percentage. Figure 2(b) shows that, with only 0.1 g nano silver, the increment of PV is up to 21%. At 0.5 g, the increment is almost doubled (i.e. 42%) while at 1.0 g, the percentage of increment is 64%. The difference between 21% and 64% increment is deemed caused by the unique physical properties of nano particles. Nano silver is naturally insoluble in water and does not combine
readily with other components in the water based drilling fluid formulation to form compounds. Therefore, due to these physical properties of nano silver, specifically (i) high solid content and (ii) high stability of waterborne particles, PV measurement was observed to be increased without the formation of additional attractive force. The Dejaguin–Landau–Verwey–Overbeek (DLVO) theory is a basis for theoretical calculations explaining nanoparticles behaviour in solution. According to DLVO theory, the stability of particles is determined by the net electrostatic surface interactions of the particles and their Van der Waals forces.

Figure 3(a)-(b). Yield point measurement of water based drilling fluid with and without the presence of nano silver. Data shown are with 5% error bar.

The net electrostatic surface interaction between the nano silver particles is further investigated by measuring the YP values. YP is the initial resistance to flow caused by the electrochemical forces between the particles [7]. Technically, it indicates how much pump pressure that must be applied during drilling operation in order to bring rock cuttings up to surface level. Meanwhile, in terms of surface interaction, high YP means attractive surface force is exhibited and low YP means steric surface force is exhibited. When YP was determined as a function of nano silver weight (n_{Ag}), a reduction of YP in the form of linear relationship \( YP = -13.71 \, n_{Ag} + 23.734 \) was reported (figure 3(a)). The percentage of reduction is shown in figure 3(b). In the presence of 0.1 g nano silver, the reduction of YP is 8.3%. At 0.5 g, the reduction is more than tripled (i.e. 29%). At 1.0 g, the percentage of reduction is in the magnitude of 5th (i.e. 58%).

Figure 4(a)-(b). Volume of filtrate measurement of water based drilling fluid with and without the presence of nano silver. Data shown are with 5% error bar.

The effect of reduced YP revealed the existence of steric force formed under fixed ionic strength condition, between the nano silver particles in a colloidal ‘water based drilling fluid’ system. In general, water based drilling fluid with a presence of nano silver has a lower YP as compared to a conventional type. This means that only low force or stress is needed in order for the drilling fluid to flow. It is indeed highly desirable to have a low YP to allow sand and shale cuttings to settle out and entrained gas to escape, minimize swabbing effect during pulling the string out of hole and permit the circulation to be started at low pump pressure (i.e. economically feasible) [7].
Figure 4(a) shows the effect of nano silver on the volume of filtrate (i.e. fluid loss) of water based drilling fluid whilst the percentage reduction is shown in figure 4(b). Without the presence of nano silver, the fluid loss is 9 mL. At 0.1 g, 0.5 g and 1.0 g nano silver, the fluid loss is 7 mL, 5 mL and 2 mL, respectively. Drilling fluid with low volume of filtrate is highly desirable when designing drilling fluid. In drilling operation, high fluid loss would cause invasion of drilling fluids and borehole instability hence could reduce reservoir potential and reduce the amount of productivity. Here, it is observed that nano silver can acts as a fluid loss additive since fluid loss is reduced in the presence of nano silver. Common fluid loss additives are bentonite, starch, and organophillic lignite.

4. Conclusion
Overall, nano silver shown an influential effect on the performance of water based drilling fluid. According to density, rheology and filtration studies, nano silver proves that it can be used as an additive in the formulation of water based drilling fluid. Specially in improving the performance of conventional water based drilling fluid, nano silver increased the plastic viscosity up to 64%, reduced both yield point and fluid loss by 58% and 78%, respectively.

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References
[1] Fattah K A and Lashin A 2016 J. African Earth Sci. 117 345–57
[2] Hassani S S, Amrollahi A, Rashidi A, Soleymani M and Rayatdoost S 2016 J. Pet. Sci. Eng. 146 183–90
[3] Akpabio J U, Inyang P N and Iheaka C I 2015 Int. J. Eng. Technol. 29-35
[4] Ariffin T S T, Yahya E and Husin H 2016 Procedia Eng. 148 1149-55
[5] Awele N 2014 Aalborg Uni. Esbjerg (Master Thesis, MSc. Oil and Gas Tech.)
[6] Dhiman A S 2012 Dalhousie Uni., Halifax, Nova Scotia (Master Thesis, Master of Eng.)
[7] Baumert M, Allouche E and Moore I 2005 Int. J. Geomech. 5 339-49