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Enhancing Drilling Fluid Performance by Introducing Nanoparticles

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Abstract: *Petroleum industry has transformed by the introduction of the nanotechnology. Drilling mud used for drilling oil and gas wells is an expensive blend of chemicals which is lost in the pores of rocks while drilling. According to study loss of drilling fluid costs approximately $800 million per year (2003 data). By introducing nanoparticles in the drilling fluid the performance of drilling fluid can be enhanced. In this study, the impact of carbon nanotubes on the properties of a water based drilling mud is investigated. The influence of nanoparticle on prevention of fluid loss is investigated by performing LPLT (low pressure low temperature) filter press test. There are several approaches for the preparation of the nano materials; namely chemical and mechanical methods. Of course there is a big difference in both of them and one can detect these variations by measuring its characterisation and properties. Characterisation of these nano materials can be done by SEM (scanning electron microscope) or TEM (transmission electron microscopy). The size and shape of the nanoparticles are generally examined by X-ray diffraction (XRD) and SEM. According to study these nanoparticles can reduce the fluid loss hence it saves the money.These particles can need further elaborate study before direct use but the potential is enormous.*

Keywords: *Drilling fluid loss, carbon nanotubes, LPLT test, SEM, XRD*

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. [1]

As early as the third century BC, the Chinese were us- ing drilling fluids, in the form of water, to help permeate the ground when drilling for hydrocarbons. The term "mud" was coined when at Spindle top in the US. Drillers ran a herd of cattle through a watered-down field and used the resulting mud to lubricate the drill.

While the technology and chemistry of drilling fluids have become much more complex, the concept has remained the same. Drilling fluids are essential to drilling success, both maximising recovery and minimising the amount of time it takes to achieve first oil.

The cost of the fluid system often represents one of the single greatest capital outlays in drilling an oil well. To minimise the cost of fluids and to ensure an efficient drilling program, the fluid properties must be maintained continuously during the drilling operation. In addition, the high temperature & high pressure conditions faced in ultra-deep oil & gas drilling environments pose major challenges for the fluids used in drilling operations. The degradation of drilling fluids in these environments reduces drilling efficiency by slowing the rates of penetration & creates severe problems that leads to leaving behind most of the oil unrecovered. [2]

A material is said to be a nano particle if at least its one dimension is less than 100 nanometers. Nanotechnology has played very important role in fields of medical, materials, monitoring, computers, etc. A lot of research has been going on in almost every field. Still we have a lot to extract from this incredible field. With even small concentration of these nano particles it has the ability to modify the properties of material to a very large extent.

Characterisation of nano materials is generally carried out by SEM(scanning electron microscope) or TEM(transmission electron microscopy). The size and shape of the nanoparticles are generally examined by X-ray diffraction (XRD) and SEM.

Bentonite is employed by industry to perform a multitude of jobs [3]. Certain industrial applications become apparent from an understanding of the composition and structure of bentonite, and the properties they create. These properties are utilised chiefly when the material is suspended in a liquid, usually water; or as a dried powder or granule. Most industrial applications involve the swelling property of bentonite to form viscous water suspensions. Depending upon the relative proportions of clay and water, these mixtures are used as bonding, plasticising, and suspending agents. Bentonite's disperse into colloidal particles and, accordingly, provide large surface areas per unit weight of clay. This large surface area is a major reason why bentonite functions so well in stabilising emulsions, or as a medium to carry other chemicals. Bentonite's react chemically with many organic materials to form compounds which are used chiefly as gelling agents in a variety of organic liquids. Bentonite's are selected for each industrial need on the basis of type and quality. This selection is based principally on physical properties, and chemistry of the bentonite becomes involved only to the extent that it influences the physical properties[2].

Drilling fluids are used in drilling operations to cool and lubricate the drill bit, remove rock debris and drill cuttings from the site and to counteract down hole formation pressures. Research is being conducted to develop nanoparticle-amended drilling fluids with enhanced functionalities. Such enhancements include improved rheological, thermal, mechanical, magnetic and optical profiles. These drilling fluids will have close to real time responsiveness (for example viscosity) to changing conditions down hole. Researchers at the National Energy Technology laboratory are designing an environmentally-friendly nanofluid for oil and gas exploration and drilling that can withstand the high temperatures and pressures in deep and horizontal drilling operations. To tackle the challenge of controlling the rheological profile of drilling muds *in situ* in response to changing environmental conditions down hole, super paramagnetic iron oxide nanoparticles are being added to create drilling fluids with viscosities that can be rapidly altered *in situ* by applying a magnetic field. Similarly, the addition of carbon nanoparticles is effective at control- ling the viscosity of drilling muds. The addition of nano- particles to drilling muds can also be used to remove the highly toxic and corrosive Hydrogen sulphide gas that diffuses into drilling fluids during drilling operations.

Researchers [4] have found that the addition of nano- scale Zinc oxide to drilling muds removes 100% of hydrogen sulphide from water-based drilling muds within 15 minutes, whereas bulk Zinc oxide removes only 2.5% after 90 minutes of treatment.

Enhanced retention or solubilization of a contaminant may be helpful in a remediation setting. Nanomaterials may be useful in decreasing sequestration of hydrophobic contaminants, such as Polycyclic aromatic hydrocarbons (PAHs), bound to soils and sediments [4]. The release of these contaminants from sediments and soils could make them more accessible to *in situ* biodegradation. For example, nanomaterials made from Poly (Ethylene) Glycol modified Urethane Acrylate have been used to enhance the bioavailability of Phenanthrene.

Metal remediation has also been proposed, using zerovalent iron and other classes of nanomaterial. Nanoparticles such as polyamidoamine dendrimers can serve as chelating agents, and can be further enhanced for ultrafiltration of a variety of metal ions (Cu(II), Ag(I), Fe(III), etc.) by attaching functional groups such as primary Amines, carboxylates, and hydroxymates [5]. Other research indicates that arsenite and arsenate may be precipitated in the subsurface using zerovalent iron, making arsenic less mobile [5]. Self-assembled monolayers on mesoporous supports (SAMMS) are nanoporous ceramic materials that have been developed to remove Mercury or radionuclides from wastewater [5].

In this study, the optimum concentration of multi-walled carbon nanotubes (MWCNTs) to generate better rheological properties in water-based drilling fluid and ester-based drilling fluid at different temperatures is investigate.[6]

2. EXPERIMENT

2.1 MATERIALS AND METHOD

For the preparation of both drilling fluid MWCNTs in powder form is used. Figure 1 show the average diameters of the MWCNTs used were 30 nm. These particular MWCNTs then were weighted by using micro-scale electronic balance at different concentration of 0.001, 0.01 and 0.1 ppb. Then each drilling fluid was prepared and test according to the standard procedures (API, 2000). Basic rheological properties were carried out such as mud weight, plastic viscosity, apparent viscosity, gel strength and filtrate loss at low pressure and high pressure and high temperature. The tests were also conducted at various temperatures of 80 F, 200 F and 250°F.

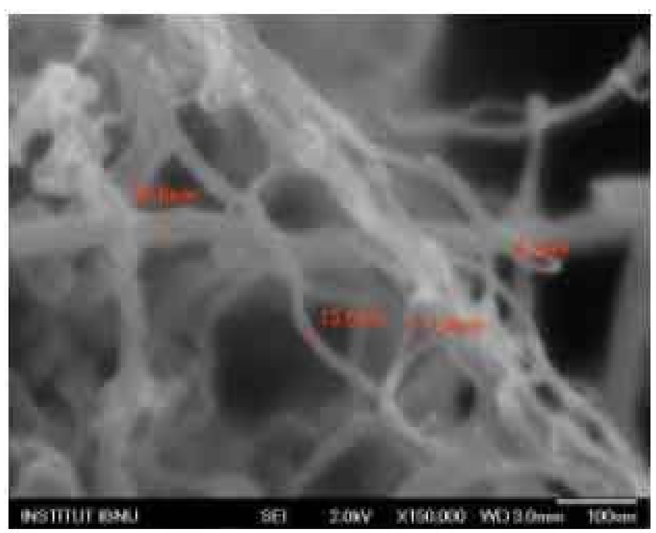

Fig. 1. Multi-walled carbon nanotube diameter under field emission scanning electron microscopy **(FESEM)**

3. RESULTS

Rheological properties of water-based drilling fluid: The experimental observation shown that not much significant variance of plastic viscosity, yield point and gel strength in water-based drilling fluid (WBDF). Figure 2 depicts that different concentration of MWCNTs used was not much affected the rheological properties of the drilling fluid.

API filtrate loss after aging at different concentration of MWCNTs used is shiwn in Fig. 3. From the Fig. 3 it revealed that 0.01 ppb addition of MWCNTs gives the lowest filtrate volume.

Rheological properties of ester-based drilling fluid: Figure 4a illustrate the effect of different concentration of MWNTs to the gel strength before aging for Ester-Based Drilling Fluid (EBDF). At 10 seconds and 10 min gel strength, the value is gradually increased. Before aging, controlled sample and 0.001 ppb are lower than acceptable range but as concentration MWNTs increase to 0.01 and 0.1 ppb the value move within the range. Sample without MWNTs gives a high value and over the range which is in between 10-20 lb/100ft^2.

Figure 4b shows the comparison of ES of controlled sample and different MWNTs concentration before and after aging. From the graph, it shows that increase in concentration does not affect the emulsion stability reading. All samples including controlled sample is within the acceptable limit which should be higher than 400 V. Sample with nanomaterial gives the higher initial value at 2048 V.

Effect of combination of MWCNTs with conventional fluid loss additive in WBDF and EBDF: In WBDF, conventional fluid loss, Pac UL with different concentration of 0.0, 0.5 and 1.0 ppb was used in order to see the effect of MWCNTs on mud filtration.

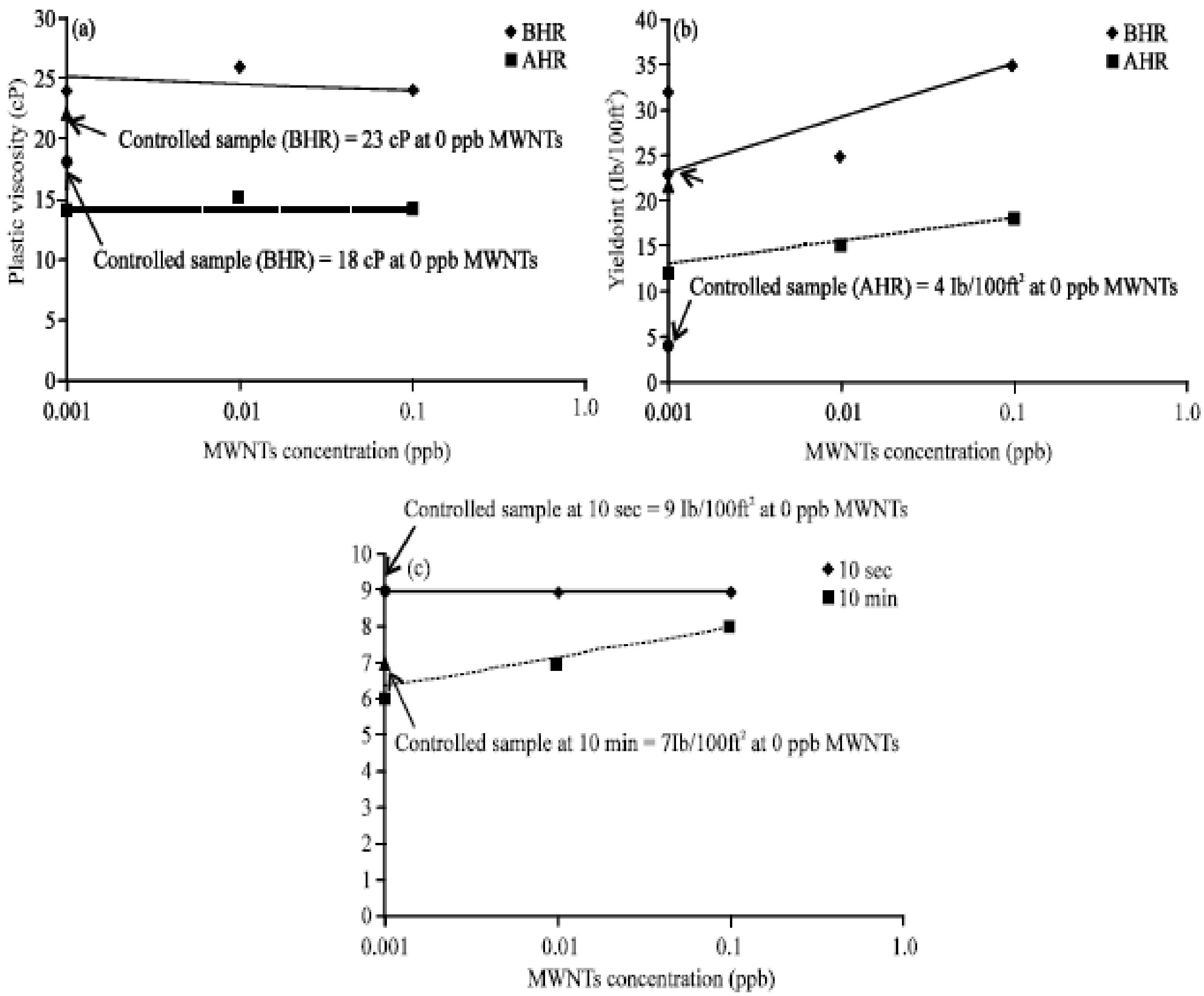

Fig. 2. (a-c). Rheological properties of water-based drilling fluid, (a) Plastic viscosity, (b) Yield point and (c) Gel strength

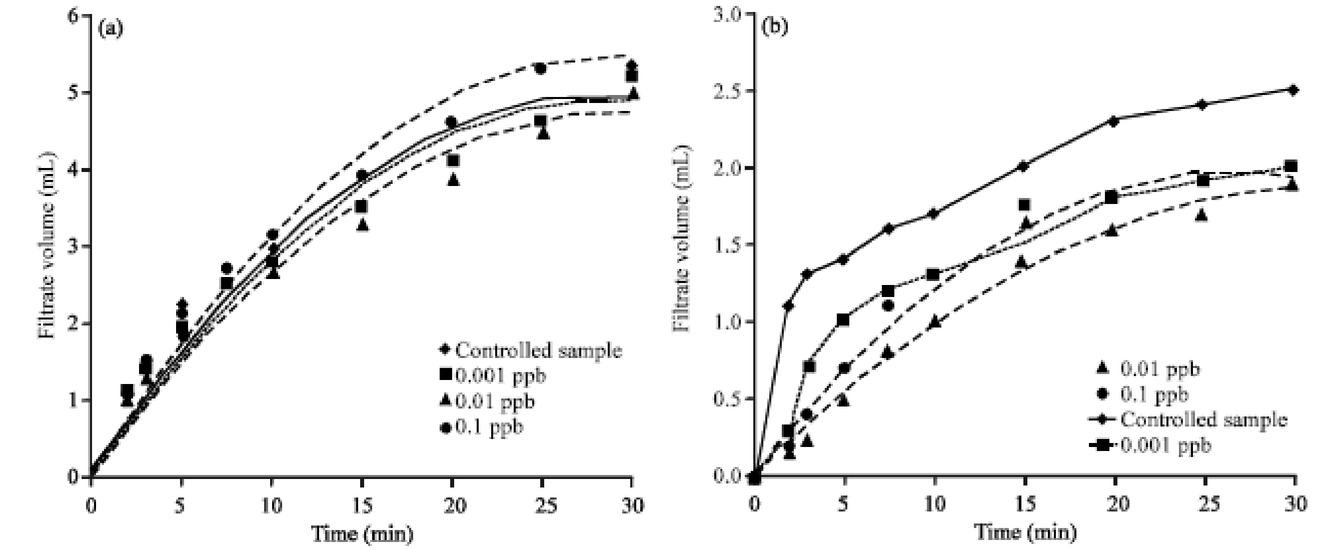

Fig. 3 (a-b). API and (b) HTHP filtrate loss after aging at different MWCNTs concentration

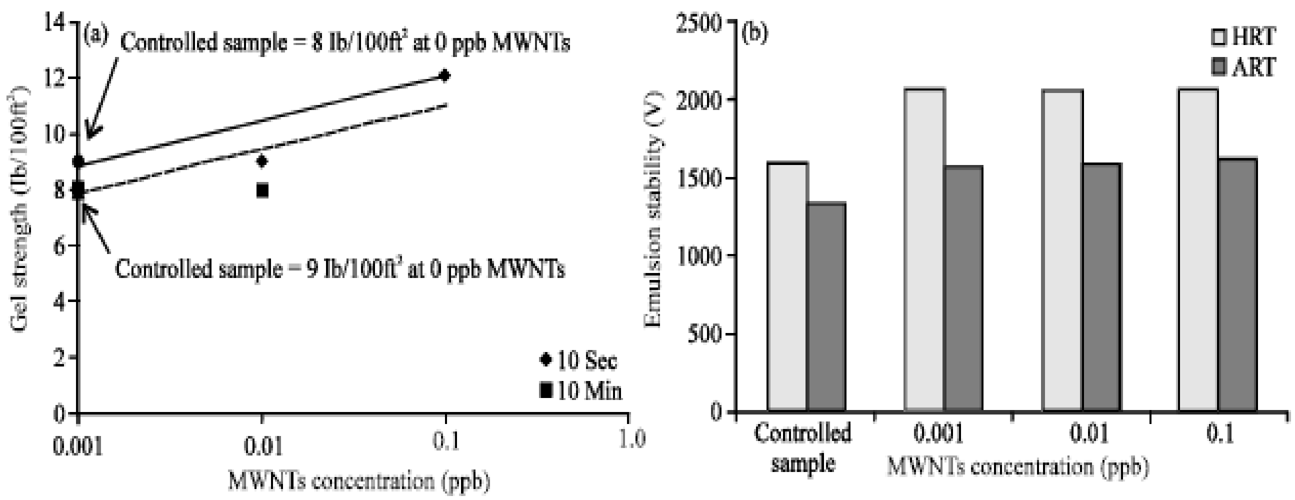

Fig. 4 (a-b). Rheological properties of ester-based drilling fluid, (a) Gel strength and (b) Emulsion stability

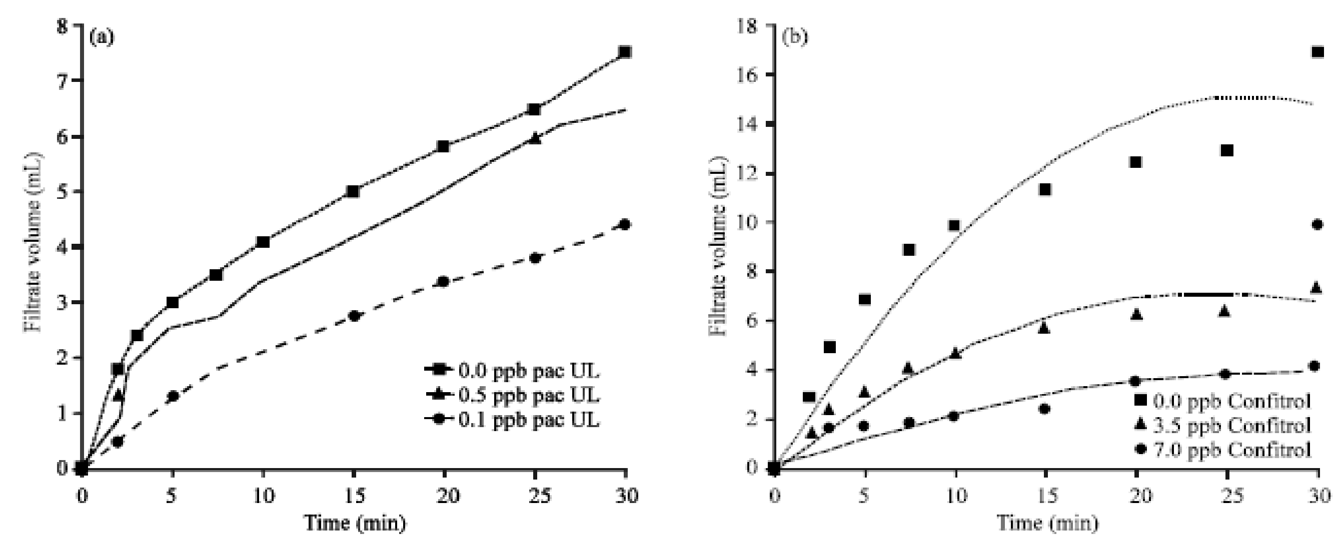

Fig. 5 (a-b). Combination of MWCNTs and conventional fluid loss, Filtrate volume of (a) WBDF and (b) EBDF

Figure 5a displayed the API filtrate loss at different concentration Pac UL and constant concentration of MWCNTs before aging. From the graph is clearly shows that with increasing Pac UL concentration will reduce the filtrate volume. Started with without Pac UL and 0.01 ppb MWCNTs in the sample, filtrate volume is high at around 7 mL. Then, addition of 0.5 ppb Pac UL and MWCNTs, filtrate volume getting reduce to about 6.5 mL. At 1.0 ppb Pac UL combined with MWCNTs gives the lowest filtrate volume of 4.3 mL.

In EBDF, confitrol was used as filtration control agent and tested in HTHP condition. In this study, 0.01 ppb of MWCNTs combined with different concentration of confitrol of 0.0, 3.5 and 7.0 ppb was used.

The effect of MWCNTs on mud filtration in EBDF before aging is given in Fig. 5b. This graph shows that filtrate volume is decrease as confitrol concentration increase at constant MWCNTs concentration.

Effect of temperature on rheological properties of MWCNTs as additive in WBDF and EBDF**:** Temperature also becomes an important indicator to show the stability of the properties of drilling mud. In this study, three different temperatures of 80°F, two other temperatures of 200 F and 250°F was evaluated to see the effect of temperature on the MWCNTs as additive in WBDF and EBDF. Figure 6a shows effect of temperature on plastic viscosity of controlled sample and different MWCNTs concentration in WBDF. As temperature increase from 80 F-250°F, plastic viscosity decrease for all sample. Although, the value is decrease but it is still in the acceptable limit. Controlled sample shows a slow decrease in plastic viscosity as compared to others. Sample with MWCNTs gives sharper slope. Besides that, at higher temperature, water viscosity decreases which results lower plastic viscosity of the mud. Temperature really gives significant impact to the plastic viscosity in WBDF. In contrast, plastic viscosity rose sharply when the temperature increase in EBDF Fig. 6c.

As can be seen in Fig. 6b is the effect of temperature to the 10 min gel strength in WBDF. As temperature increase, gel strength is decrease for all samples. In EBDF gel strength also affected by changing in temperature. At elevated temperature, gel strength reading getting higher as shown in Fig. 6d. Although the gel strength of sample with MWNTs is gradually increase as temperature increase but the value is still lower as compared to the controlled sample. Controlled sample gives higher gel strength value at higher temperature which exceed the acceptable limit.[6]

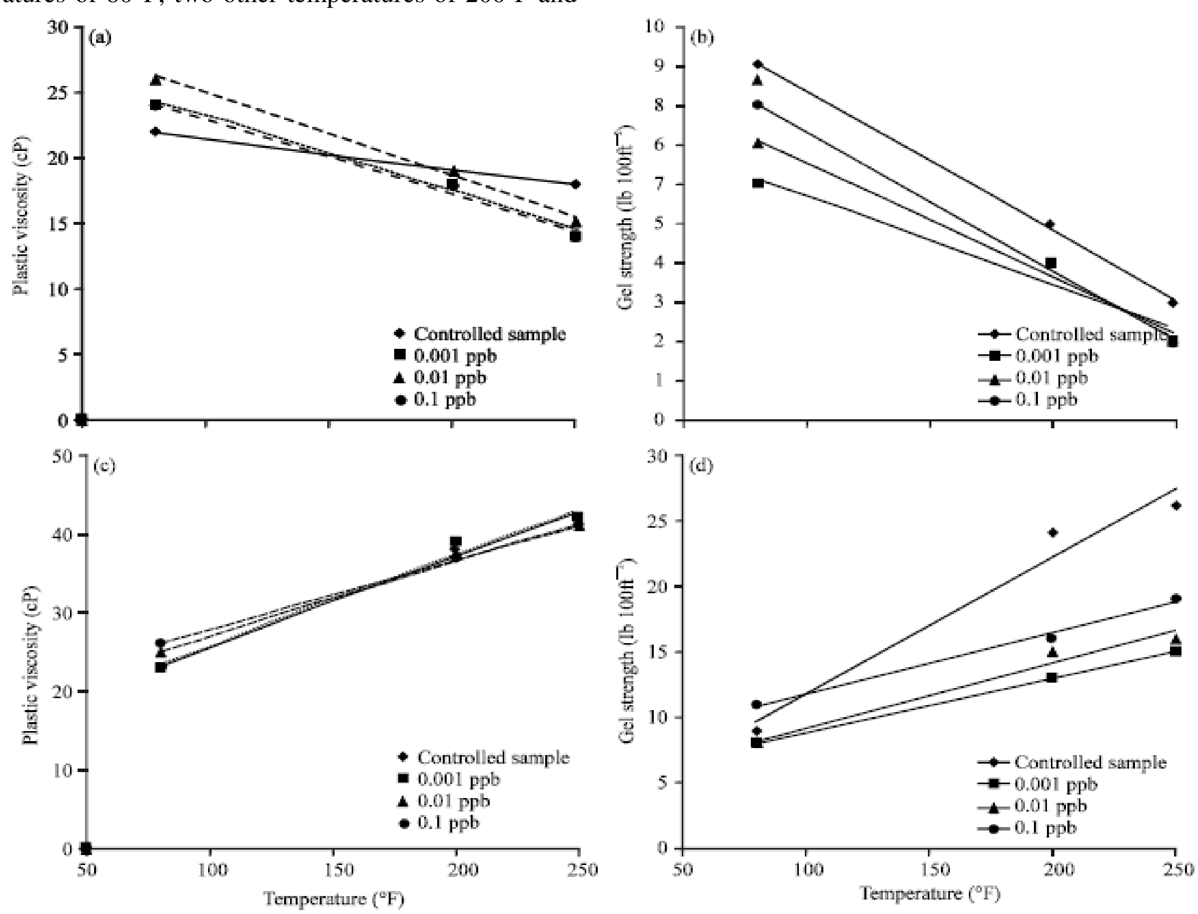

Fig. 6 (a-d). Temperature effects on WBDF, (a) Plastic viscosity, (b) Gel strength, EBDF, (c) Plastic viscosity and (d) Gel strength

4. DISCUSSION

Rheological properties of drilling fluids: Water-based drilling fluid shows not much significant variance of plastic viscosity and yield point. The constant value for the gel strength of water-based drilling fluid gives the same features as the previous report that stated flat type gel strength property of the nano-based drilling fluid indicates superior functional functional behaviour while drilling [7]. Addition of 0.01ppb of MWCNTs gives the lowest filtrate volume as compare to others concentration. Other samples give higher volume than acceptable limit. This condition occur might because of the mud become less stable due to the solid accumulation. As a result, impermeable mudcake with lower porosity is not obtained and more filtrate can pass through the mudcake. In HPHT condition, 0.01 ppb of MWCNTs still gives the lowest filtrate volume. Both API and HTHP condition observed to have no spurt loss especially when adding nanomaterial. This property was very good in reducing the scope of formation damage in damage prone oil and gas reservoir [7].

For ester-based drilling fluid, small difference value of 10 sec and 10 min gel strength gives the shape is almost flat type of gel strength which is same as WBDF. Lower gel strength reading after 10 min may due to reducing in the shear rate of the mud. Moreover, reduction of the yield point may also become another factor that affect the gel strength reading. Emulsion Stability (ES) is one of the important indicators in EBDF to show that oil and water is well mixed. Higher value of sample with nano material is good in drilling operation because emulsion stability is getting reduced with increasing temperature and pressure. Emulsion stability of the nano-based drilling fluid is relatively high might because of the high electrical stability criteria of MWNTs itself. Small amount of MWNTs is enough to increase the emulsion stability of the mud. Effect of combination of MWCNTs with conventional fluid loss additive in WBDF and EBDF: Addition of small concentration of MWCNTs in WBDF can help to improve in reducing filtrate loss through the formation. MWCNTs still required conventional filtration control agent to control fluid loss in the mud. Increase in Pac UL concentration results in an increase available binding site on it. These active sites will react with the base oil to form a homogeneous mud system thus reduce the porosity of the filter cake. Besides, increasing Pac UL concentration in the mud is expected to further reduce fluid loss through the filter cake. Same condition is observed on EBDF. Increase of confitrol concentration gives increase the active sites react with base oil. This homogeneous reaction helps in further reduce the porosity of the filter cake formed. Addition of MWCNTs as additive in this type of mud is not much influence the mud filtration property. Higher concentration of MWCNTs perhaps is required to obtain a better result. Effect of temperature on rheological properties of MWCNTs as additive in WBDF and EBDF: High temperature leads to reduce in emulsion stability of the mud. This condition is believed to cause solid accumulation. High solid accumulation gives is not favourable as it results high plastic viscosity, reduce the gel strength as well as yield point of the water- based drilling fluids. In EBDF, high gel strength value in the mud is because of high yield point at higher temperature. Solid accumulate in the mud will increase the attractive force between a particles thus resulting higher gel strength.[6]

5. CONCLUSIONS

This study shows that MWCNTs can be used as an additive in drilling fluid. The following conclusion can be derived from this research:

- Rheological properties (plastic viscosity, gel strength and filtrate loss) show better improvement with the addition of MWCNTs
- Increase concentrations of MWCNTs in ester based drilling fluid provide better result in plastic viscosity, gel strength, emulsion stability and filtrate loss.
- Combination of MWCNTs with commercial fluid loss control agent such as Pac UL give better filtrate controller.
- An increase in temperature will affect the rheological properties in both water based and ester based drilling fluids. However, an increase in temperature did not give significant impact to the fluid loss and emulsion stability[6]

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