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AN EXPERIMENTAL INVESTIGATION ON USE OF MULTI-WALLED CARBON NANOTUBES TO IMPROVE THE PERFORMANCE OF AN OILFIELD APPLICABLE WATER-BASED DRILLING FLUID

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Abstract— Multi-walled carbon nanotubes (MWCNTs) is one of the novel nanomaterials in the industry. In this research, the MWCNTs was added to an industrial water based drilling fluid as a substitution for polyanionic cellulose (PAC-LV) to reduce the fluid loss volume under LP-LT well condition. The effects of different concentrations of MWCNTs addition on the rheological and filtration properties and filter cake characteristics was investigated. The achieved results of this work proved that the fluid loss volume of the water based drilling fluid is decreased about 46.5% in the presence of 1.75 gr MWCNTs. In addition, the mud cake characteristics and rheological properties such plastic viscosity, yield point and gel strength of nanofluids with different concentrations of MWCNTs were better than the based fluid which had PAC-LV in its formulation. The successful use of MWCNTs showed that this nano materials can replace in water-based drilling fluid instead of PAC-LV to improve the drilling fluid performance.

Keywords — Filtrate Volume ,Filter Cake Thickness, Fluid Loss Volume, Rheological Properties, Water base Drilling Fluid, Multi-Walled Carbon Nano Tubes.

1-Introduction

The success of drilling oil and gas wells are highly relying on the drilling mud utilized during drilling and completion operations, therefore, design and formulate a suitable drilling fluid which has good rheology and filtration properties is an important key to a successful drilling operation (A.R Ismail, Tan. C Seong, N. A. Buang, & Sulaiman, 2014; Hareland, Wu, Lei, Husein, & Zakaria, 2012) .Filtration loss (fluid loss) is a measure of the relative amount of fluid invaded (filtrate) through permeable formations when the drilling fluid is exposed to a pressure differential (Nmegbu, 2014).F (Park et al., 2012)filtration control is so important during a well drilling to minimize the expenditures of the drilling fluids and also decrease the formation damage which is a challenge that happens because of the invasion of the mud filtrate into the permeable formation. Most of the drilling fluids have solid particles such as clays, barite and etc. which these solid particles can migrate by filtrate invasion into the formation and bridge in the formation pores entrance which it can damage the formation, Overly, filtrate invasion into reservoir formation can reduce the productivity of the well by closing the exit flow paths of the hydrocarbon and collapsing the formation pores (A.R Ismail, Tan. C Seong, N. A. Buang, & Sulaiman, 2014).many different additives usually have been used to control and minimize the filtration loss volume such as starch, lignosulfonates, bentonite and some polymers (Krueger, 1963) . Nanotechnology comes to the interest of oil and gas industry as a candidate that offer the solution for the above challenges due to its special character (A.R Ismail, Tan. C Seong, N. A. Buang, & Sulaiman, 2014). Carbon nanotubes (CNTs) are graphitic carbon hollow nanometer size tubes of graphitic carbon. A carbon nanotube can be supposed as a graphene sheet rolled in the form of a seamless cylinder. CNTs can be separated into two main types: the first type is single-walled carbon nanotubes (SWCNTs) and another type is multi-walled carbon nanotubes (MWCNTs). A single-walled carbon nanotube can be depicted as a single graphene sheet rolled into a tube, whereas, the multi-walled nanotubes can be depicted as a number of concentric SWCNTs which different diameters (Ahmad et al., 2013). A variety of nano materials has been used in recent research on drilling fluids to improve the rheological properties and minimize the fluid loss volume of the drilling fluids. Abdul Razak Ismail et al, investigated the effects of nano metal oxides such aluminum oxide, copper oxide and titanium oxide on the performance

of a water-based drilling fluid. The rheological and filtration characteristics of each mud samples with different nano metal oxides were evaluated by HP-HT filter press and rotational viscometer. They proved that use of nanoparticles into water base drilling fluid at HPHT condition have better results since the fluid loss and the filter cake thickness was reduced. For example, the addition of 1 gr titanium oxide in the water-based drilling fluid resulted more than 50% reduction in filtration loss and the mud cake thickness reduced to about 30%. 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 (A.R Ismail, Tan. C Seong, N. A. Buang, & Sulaiman, 2014). Adel M. Salem Ragab et al, showed in their work that the nanoparticles of silicon oxide (SiO_2) can be utilized in the drilling fluid to improve its filtration properties and reduce the fluid loss volume. Their results proved that silica nanoparticles can be more effective to reduce the filtrate volume than conventional fluid loss control additive such PAC-LV and PAC-HT (Ragab & Noah, 2014). The objective of this work is that use the MWCNTs as a substitution for low viscosity polyanionic cellulose (PAC-LV) to minimize the fluid loss volume in a field applicable water based drilling fluid which is being used for drilling a well at the low-pressure low-temperature condition in one of the Iranian oilfields. Additionally , the use of nanoparticles may successfully improve the rheological properties of the drilling fluid because of the specific properties of nanomaterials. The successful using of MWCNTs can convince that this nano-Materials is applicable in the industrial drilling fluid for using in the oilfield drilling operations to reduce and minimize the formation damage which may happen due to the fluid loss through the reservoir formation.

2-Matrials and Methods

2-1- Testing Equipment

The equipment which was used in this used in this work comprises Hamilton beach mixer, digital pH meter, mud balance, Fann viscometer, API LT-LP filter press, measuring cylindrical tube, vernier caliper.

2-2- Materials

The materials which were utilized in the formulation and their function to prepare the mud samples are presented in table 1.

Table 1- The materials and their function

Component	*Function*
Water	*The continuous phase of drilling mud sample*
Caustic soda	*pH modifier additive*
Soda ash	*pH modifier additive*
Sodium chloride	*shale inhibitor and d weighting agent*
Potassium chloride	*Used as shale inhibitor additive*
Polyanionic cellulose (PAC)	*Used as a fluid loss control additive*
Limestone	*weighting agent*
Starch HT	*viscosifire and fluid loss control additive*
XC polymer	*viscosifire additive*
Multi-walled Carbon Nanotubes	*fluid loss control additive*

2.3 Multi-Walled Carbon Nanotubes Characterization

Multi-walled carbon nanotubes are one of the novel nanomaterials in the industry. The specification of the MWCNTs which was used in the experiments is presented in table 2. Scanning Electron Microscopy (SEM) image of MWCNTs which was used in the experiments is shown figure 1.

Table 2 specification of the multi-walled carbon nanotubes	
Criteria	***Details***
Product name	***Multi-walled carbon nanotubes***
Purity	***95 wt% (carbon nanotubes)***
Outside diameter	***20-30 nm***
Inside diameter	***5-10 nm***
Length	***10-30 um***
Color	***Black***
True density	***2.1 g/cc***

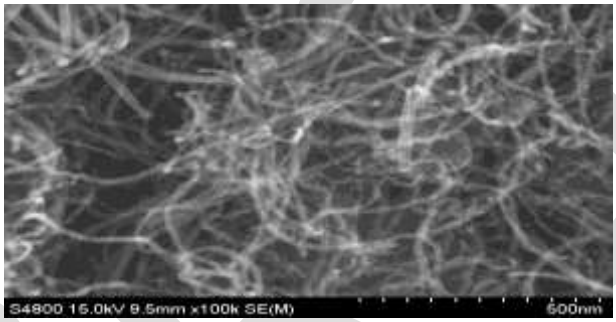

Figure 1- SEM imaging of MWCNT

2-4 Mud Sample Preparation

A field applicable mud formulation which has being used to drill a well in one of the Iranian oilfields was selected and four mud sample were designed and formulated which the mud formulations are presented in table 3. From table 3, It can be noticed that there were no multi-walled carbon nanotube (MWCNTs) in the base mud sample but the other samples, MWCNT with different concentration was subtracting in the mud formulation as fluid loss control agent instead of the PAC-LV to examine the performance of nano additive as filtration control additive in compared to PAC-L.

table 3- water based drilling fluid formulation				
Component	Base Mud	Mud 1	Mud 2	Mud 3

Water (bbl)	350	350	350	350
Caustic soda (lb/bbl)	0.5	0.5	0.5	0.5
Soda ash (lb/bbl)	0.5	0.5	0.5	0.5
Sodium chloride (lb/bbl)	90.8	100	100	100
Potassium chloride (lb/bbl)	20	15	15	15
Polyanionic cellulose (lb/bbl)	1.75	–	–	–
Limestone (lb/bbl)	60	30	30	30
Starch HT (lb/bbl)	8.9	8.9	8.9	8.9
XC polymer (lb/bbl)	0.6	0.6	0.6	0.6
MWCNT (wt. %)	–	1	3	5

3- Results and discussions

3-1 Effect of MWCNTs Concentration on the density and pH value of drilling fluid

The nanofluid samples and the base mud have the same value of pH which is about 9.5 .According to that nanoparticles have low density and the amount of used nanoparticles to formulate the samples is small so the density of the nanofluid samples and the base mud is equal and the density of the mud sample is 10.5 pound per gallon.

3-2 Effects of MWCNTs Concentration on the drilling fluid Rheology

The rheological performance of drilling fluid can be defined in three characteristics of the fluid which are plastic viscosity (PV), yield point (YP) and gel strength. Plastic viscosity is the Fluid resistance to flow which is due to mechanical friction between the solid phase and liquid phase of drilling fluid .the another component of the fluid resistance to flow in Bingham plastic model is yield point which is due to electrochemical forces between the particles under the conditions of flowing. These electrochemical forces are the result of charges positioned on the surface the particles which are dispersed in the fluid phase. The strength of attractive force (gelation) in the satirical conditions is defined as fluid gel strength (Wahid, Yusof, & Hanafi, 2015). The rheological properties of the mud samples were measured by a rotational viscometer and the comparison of plastic viscosity and yield point for the samples which were obtained from two different speeds (300 and 600) of rotational viscometer dial reading based on Bingham Plastic Model are presented in figure 2.

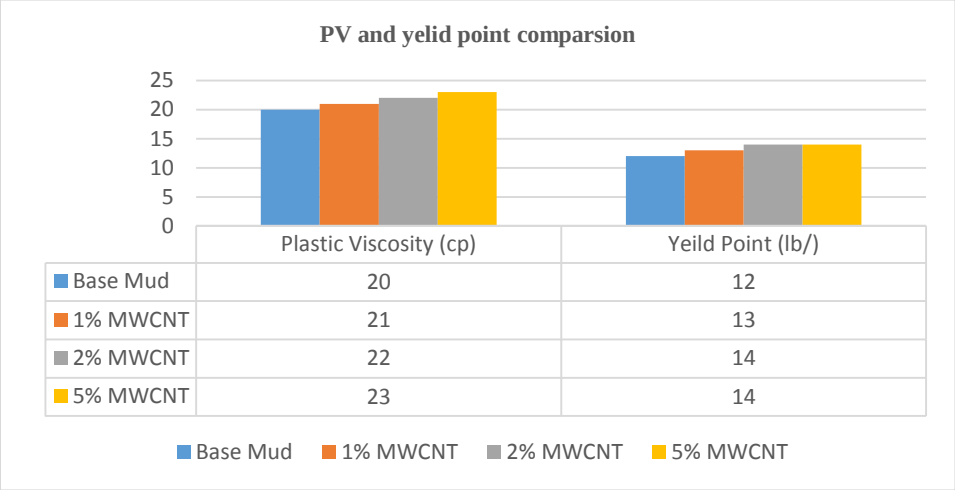

Figure 2- The comparison of plastic viscosity and yield point

Nano Materials have more surface area per volume than other materials such micro and macro sized Materials. The nanoparticles surface area can serve as places for bonding with functional groups can affect chain entanglement and therefore can create a wide range of properties in the matrix. Therefore, the base fluid and the nanoparticles may be created a bond with each other directly or through certain intermediate chemical linkages to make better the plastic viscosity of water based drilling fluid (Quintero, Cardenas, & Clark, 2014) . The results in figure 2 show that the mud samples which includes MWCNTs in its formulation had higher values of plastic viscosity and yield point values than the base mud sample. In addition, as the concentration of nano-materials increased in the samples their plastic viscosity increased and yield point which the highest plastic viscosity and yield point value is observed for mud sample with 5 weight percent of MWCNTs. The comparison of gel strength 10 minute and 10 seconds between the muds samples are shown in figure 3. Figure 3 shows that as the concentration of MWCNTs increases in the samples both values of gel strength increases. This increase in gel strength value is due to the attractive force between nanoparticles which form a rigid structure by creating a linkage between nanoparticles and base fluid during 10 seconds and 10 minutes period (A.R Ismail, Tan. C Seong, N. A. Buang, & Sulaiman, 2014). By comparing the results of nanofluids and the base mud it can be proved that the nanoparticles can properly improve the rheological properties of drilling mud.

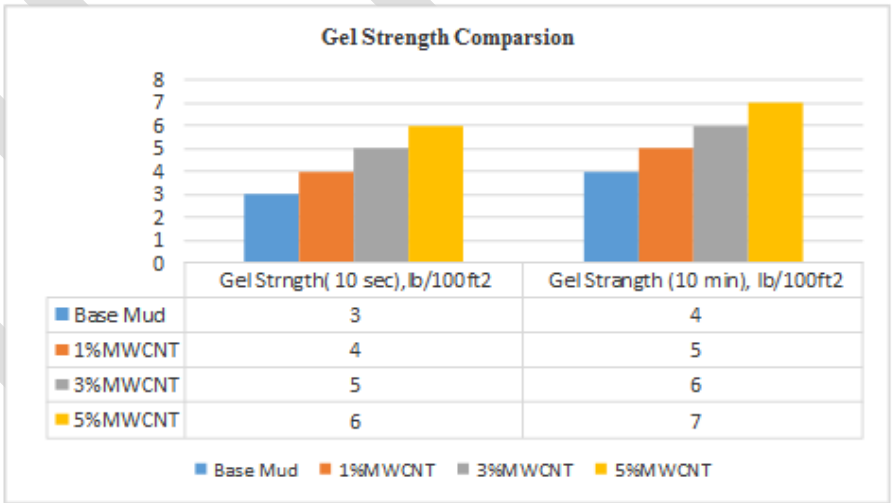

Figure 3- The comparison of Gel strength 10 min and 10 sec

3-3 Effects of Nanoparticles Concentration on the Mud Flirtation Properties

.The fluid loss of drilling mud should have the lowest value during the drilling operation to reduce the formation damage and prevent from the tight hole and differential pipe sticking. API LT-LP filtration tests were done on the mud samples to investigate the mud cake

thickness and quality and fluid loss volume loss for the mud sample under 100 psi pressure and room temperature condition. The volume fluid loss which was collected from the samples within thirty minutes filtration tests period is shown in table 4.

Table 4- The filtrate volume for the drilling mud samples

Time (min)	Filtrate volume (mL)			
	Base Mud	Mud 1	Mud 2	Mud 3
5	2.2	1.8	1.6	1.4
10	3	2.6	2.3	1.9
15	4.4	3.3	2.8	2.4
20	4.9	3.6	3.1	2.7
25	5.4	3.9	3.4	2.9
30	5.8	4.2	3.7	3.1

From the table 4, it can be noticed that generally, the addition of MWCNTs into mud sample formulation can significantly reduce the amount of collected filtrate volume during the test. The increase in nanoparticles concentration has a significant effect on filtrate volume which the smallest amount of filtrate volume observed for the sample by addition 5% MWCNTs in its mud formulation that is about 3.1 ml. there is a reduction of 46.55 %, 27.58% and 36.20% in passed filtrate volume from the mud cake during 30 minutes, respectively for the sample with 1%MWCNTs, 2% MWCNTs and 5% MWCNTs. The reduction of filtrate volume for Nanofluids is due to that the dispersed MWCNTs in the mud samples can act as plaster between the particles and seal the permeable formed mud cake to decrease the filtration loss (Park et al., 2012).The comparison of the thickness of filter cake of the samples is presented in figure 4.

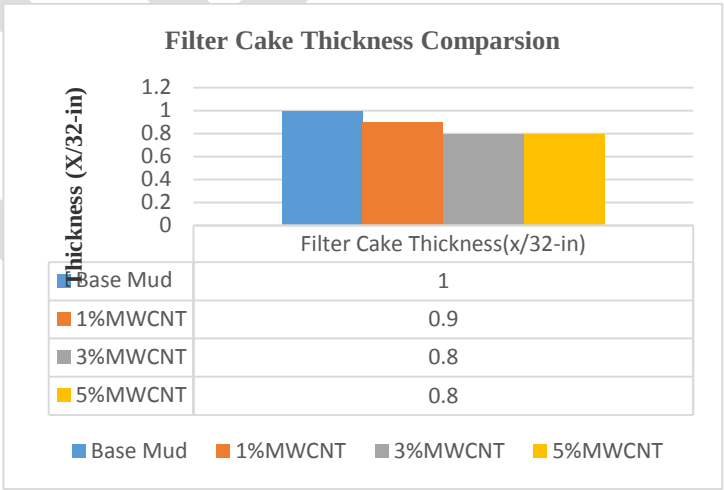

Figure 4 –The comparison of the thickness of filter cake for the

samples

From figure 4 it can be seen that the thickness of the formed mud cake from the nanofluids is thinner than the base mud filter cake thickness. In addition, the MWCNTs concentration increasing in the Nanofluids formulation does not dramatically change the filter cake thickness. The results of the rheology a filtration tests convinced that multi-walled carbon nanotube can substitute in mud formulation instead of polyanionic cellulose to improve the rheological properties and filtration properties of drilling fluid. Nanoparticles had a great effect on filtration properties which it observed the nanofluid had a smaller amount of fluid loss that can reduce the formation damage and the thinly formed filter cake of nanofluids can reduce the risk of differential sticking pipe. The most important aspect of this work is that the multi-walled carbon nanotube is applicable for using in the field mud formulation as it observed 1% MWCNTs had better filtration and rheology in compare to the base sample which had of 5 Wight percent PAC-LV as fluid loss control additive.

4- Conclusion

The multi-walled carbon nanotubes can use as fluid loss control additive in the mud formulation by 46 .5% reduction in the filtrate volume which was produced during the filtration test in compared to the base sample. An in an increase in MWCNTs concentration can properly increase the rheological properties such as of yield point, plastic viscosity and gel strength of the water base drilling fluid. The successful use of multi-walled carbon nanotube shows that MWCNT is more effective in improving the rheological properties and reducing the fluid loss than the commercial fluid loss control agent such low viscosity polyanionic cellulose, therefore, MWCNTs can be used as a substitution for PAC-LV in the mud formulation because of its a great capability to reduce the fluid loss and improve the rheology of the mud. According to that the selected water-based mud formulation for the work is an industrial (field applicable) formulation therefore the results of the tests proved that MWCNTs can utilize in the oilfield drilling operations to improve the performance of water-based drilling fluid.

REFERENCES:

1. A.R Ismail, Tan. C Seong, N. A. Buang, & Sulaiman, a. W. R. N. (2014). *Improve Performance of Water-based Drilling Fluids Using Nanoparticles*. Paper presented at the The 5th Sriwijaya International Seminar on Energy and Environmental Science & Technology, Indonesia.
2. Ahmad, S. N., Hakeem, S., Alvi, R. A., Farooq, K., Farooq, N., Yasmin, F., & Saeed, S. (2013). *Synthesis of multi-walled carbon nanotubes and their application in resin based nanocomposites.* Paper presented at the Journal of Physics: Conference Series.
3. Hareland, G., Wu, A., Lei, L., Husein, M. M., & Zakaria, M. F. (2012). *Innovative Nanoparticle Drilling Fluid and Its Benefits to Horizontal or Extended Reach Drilling.* Paper presented at the SPE Canadian Unconventional Resources Conference.
4. Krueger, R. F. (1963). Evaluation of drilling-fluid filter-loss additives under dynamic conditions. *Journal of Petroleum Technology, 15*(01), 90-98.
5. Nmegbu, C. G. J. (2014). Bacteria as a Filtration Loss Reducing Agent during Drilling. *international journal of engineering and research and application, Vol. 4*(Issue 6), 191-194.
6. Park, J., Kim, G., Yoon, D., Sin, C., Park, I., Bea, T., & Lee, M. (2012). The Effect of Dispersed MWCNTs Using SDBS Surfactant on Bacterial Growth. *World Academy of Science, Engineering and Technology, 6*, 697-700.
7. Quintero, L., Cardenas, A. E., & Clark, D. E. (2014). Nanofluids and methods of use for drilling and completion fluids: Google Patents.
8. Ragab, A. S., & Noah, A. (2014). Reduction of formation damage and fluid loss using nano-sized silica drilling fluids. *Petroleum Technology Development Journal, 2*, 75-88.
9. Wahid, N., Yusof, M. A. M., & Hanafi, N. H. (2015). *Optimum Nanosilica Concentration in Synthetic Based Mud (SBM) for High Temperature High Pressure Well.* Paper presented at the SPE/IATMI Asia Pacific Oil & Gas Conference and Exhibition.