EVALUATION OF NANCOMPSITE POLYPROPYLENE- NANOSILICA AS FLUID LOSS CONTROL MATERIAL FOR HIGH PRESSURE HIGH TEMPERATURE CONDITION

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ABSTRACT

A potential additive for water-based mud which is the newly synthesized nanocomposite polypropylene based nanosilica (PP-SiO2 NC) has showed promising results in reducing shale swelling, enhancing cutting transport efficiency and reducing the fluid loss, but at low temperature only. Therefore, in this study, the efficiency of filtration loss was carried out for high temperature high pressure (HPHT) and its performance was compared to the commercial filtration agent Polyanionic Cellulose (PAC) at the simulated reservoir conditions. 7 samples of mud were prepared from 0.5 to 1.5 gram of (PP – SiO2 NC) PAC mud. The effect of temperature on the critical rheological properties such as plastic viscosity (PV), yield point (YP), gel strength (GS) and pH at the above concentrations were evaluated. Then, the effect of (PP – SiO2 NC) on filtration loss was evaluated at following conditions. First, at 100 psi as constant pressure and ambient temperature using the standard American Petroleum Institute (API) filtration method. The second filtrate loss measurement is at high pressure high temperature (HPHT) conditions. For HPHT measurement, it was tested at 250 oF temperature while the pressure was 500psi as differential pressure. Addition of both PAC and PP – SiO2 NC before ageing improved the properties of the WBM. There are no much variation between the rheology PV,YP and GS of PAC and PP – SiO2 NC . The PV of the WBM with PP – SiO2 NC has an optimum value at 1g concentration while the addition of PAC into WBM increases the PV with increasing concentration. After ageing PV for both the PAC and PP – SiO2 NC with a concentration of 1.5g and 1g respectively increased by 53.8 % and the YP of PAC increased by 25%, while for the PP – SiO2 NC mud improved by 40% compared to basic mud. The lower API filtration loss and mud cake thickness were obtained through adding 1.5g PAC .In the other hand at HPHT test showed a prospective reduction in the fluid loss and the best result was achieved by adding 1.5 g of PP-SiO2 NC 67.7% compared to basic mud. In addition, at HPHT It was observed that filter cake characteristic was improved by obtained thin and low permeability mud cake observation made indicated that the filter cake thickness and permeability for the samples with different concentrations of PP – SiO2 NC were lower than that of PAC the lowest values of mud cake thickness and permeability 50% and 85.2% respectively through adding 1.5g PP-SiO2 NC compared to basic fluid.

ABSTRAK

Salah satu potensi bahan tambahan bagi lumpur berasaskan air adalah komposit nano berasaskan poplipropilena (PP-Si02 NC) telah menunjukkan keputusan yang menjanjikan bagi mengurangkan penambahan shale, meningkatkan efisiensi pengangkutan bahan potongan dan mengurangkan kehilangan bendalir, tetapi di suhu yang rendah sahaja. Oleh itu, dalam kajian ini, efisiensi kehilangan bendalir dijalankan di suhu dan tekanan yang tinggi dan kebolehannya dibandingkan dengan agen penapisan komersil, Polyanionic Cellulose (PAC) disimulasi di kondisi takungan. 7 sampel lumpur disediakan dengan 0.5-1.5 gram (PP-SiO2 NC) lumpur PAC. Kesan suhu pada sifat rheologi kritikal seperti kelikatan plastik (PV), titik alah (YP), kekuatan gel (GS) dan pH pada kepekatan di atas dinilai. Kemudian, kesan (PP-SiO2 NC) pada kehilangan bendalir dinilai pada kondisi berikut. Pertama sekali, 100 psi tekanan malar dan suhu persekitaran berdasarkan standard cara penapisan American Petroleum Institute (API). Penapisan yang kedua adalah pada suhu dan tekanan yang tinggi (HPHT). Bagi ukuran HPHT, ia diuji pada suhu 250°F dan tekanan 500 psi bagai perbezaan tekanan. Tambahan kedua PP-SiO2 NC sebelum penuaan meningkatkan sifat lumpur berasaskan air. Tiada banyak variasi di antara PV, YP dan GS kepada PAC dan PP-SiO2 NC. PV bagi lumpur berasaskan air dengan PP-SiO2 NC mempunyai nilai optimum pada kepekatan 1g, manakala tambahan PAC ke dalam lumpur berasaskan air menaikkan PV dengan meningkatkan kepekatan. Selepas penuaan, PV bagi kedua PAC dan PP – SiO2 NC bagi kepekatan 1.5 g dan 1 g menaik sebanyak 53.8% dan YP bagi PAC menaik sebanyak 25%, manakala bagi lumpur PP – SiO2 NC meningkat sebanyak 40% dibandingkan dengan lumpur asas. Pengurangan bagi kehilangan penapisan dan ketebalan kek lumpur didapati dengan cara menambah 1.5g PAC. Selain itu, pada ujian HPHT telah menunukkan prospek pengurangan kehilangan bendalir dan keputusan terbaik adalah dengan menambah 1.5 g of PP-SiO2 NC 67.7% dibandingkan dengan lumpur asas. Tambahan pula, pada HPHT, diperhatikan karakter kek lumpur telah meningkat dengan mendapatkan kek lumpur nipis dan kebolehtelapan yang rendah. Perhatian dibuat menunjukkan ketebalan kek lumpur dan kebolehtelapan bagi sample dengan kepekatan yang berbeza PP – SiO2 NC adalah lebih rendan berbanding PAC dan nilai terendah bagi ketebalan kek lumpur dan kebolehtelapan adalah 50% dan 85.2% selepas menambahkan 1.5g PP-SiO2 NC dibandingkan dengan lumpur asas.

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LIST OF ABBREVIATIONS

KCl	Potassium Chloride
PP-SiO2	Polypropylene Nanosilica
PNC	Polymer Nanocomposites
PAM	Polyacrylamide
LPLT	Low Pressure Low Temperature
HPHT	High Pressure High Temperature
PPgMA	Polypropylene Grafted Maleic Anhydrite
PP	Polypropylene
NP	Nanoparticles
MA	Maleic Anhydride
SiO2	Nanosilica
CEC	Cation Exchange Capacity
WBD	Water Based Drilling
OBM	Oil Based Mud
CMC	Carboxy Methyl Cellulose
PAC	Polynomic Cellulose
PHPA	Partially Hydrolized Polyacrylamide
XG	Xanthan gum
PV	Plastic Viscosity
YP	Yield Point
GS	Gel Strength
API	American Petroleum Institute
MWCNT	Multiwall Carbon Nanotube

LIST OF SYMBOLS

dv/dt	Filtration Flow Rate
K	Filter Cake Permeability
A	Filter Cake Cross-Sectional Area
ΔP	Differential Pressure
μ	Filter Loss Viscosity
h	Filter Cakes Thickness

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Drilling fluids have gone over considerable technological development since the initial steps using a mixture of clays and water to compound mixtures of various organic and inorganic drilling fluid additive products. Drilling fluids are very essential part of the drilling operation. The drilling process success depends massively on the achievement of the drilling fluid being used. In typical drilling situations, drilling fluids represent up to one fifth (15 to 18%) of the total expense of well drilling however in harsh losses conditions, it may cost up to 40% of overall well cost (Ragab & Noah, 2014). So, drilling fluid optimum selection type and characteristics is the essential key in minimizing drilling time and costs especially in the current global challenge of low crude oil prices (Amanullah, AlArfaj, & Al-abdullatif, 2011).

Drilling fluids are designed to fulfill certain functional tasks such as controlling formation pressures, hole cleaning, minimizing formation damage, cooling and lubricating drill bits and maintaining wellbore stability. These functions can be achieved by proper treatment of drilling fluid properties such as mud density, PV, apparent viscosity (AV), YP, gel strength, mud filtrate loss volume, lubricity, and shale inhibition. These functions have to be performed consistently throughout the operation regardless of the type of formation and operating conditions. Lack in performing any of these functions leads to severe drilling problems like: stuck pipe, lost circulation, high torque and drag, formation damage, poor hole cleaning and wellbore instability problems with changing conditions (Abduo, Dahab, Abuseda, AbdulAziz, & Elhossieny, 2016).

The choice of the drilling fluid and its additives becomes more complicated especially when more products of various functions are introduced from time to time. Although, the drilling fluids technology and chemistry have become much more complex, the concept has remained the same. WBM consists of fresh or sea water as based fluid mixed with different chemical additives to obtain the certain desired fluid properties, the Table 1.1 shows the most commonly used DF additives with their functions (Khan, Sardar, & Khan, 2016).

Table 1.1 Drilling Fluid products and functions (Khan et al., 2016).

DF Functions	Materials names
Weighting Agents	Barite, Hematite, iron oxides, calcium carbonates and similar products possessing high specific gravity
Thinning Agents and Viscosifiers	Bentonite, attapulgite, xanthan Gum and Poly Anionic Cellulose High Viscosity (PAC HV)
Filtration Control Additives	Carboxy Methyl Cellulose (CMC), Partially Hydrolyzed Polyacrylamide (PHPA), Poly Anionic Cellulose Low Viscosity (PAC LV), Poly Anionic Cellulose High Viscosity (PAC HV), Drill Amyl and Modified Starch
Flocculants	Sodium Chloride (NaCl), Potassium Chloride (KCL), Hydrated Lime, Calcium Hydroxide, Gypsum, Calcium Sulphate, Soda Ash, Sodium Carbonate, Sodium Bicarbonate, Tetrasodium, Pyrophosphate and Polyacrylamide Polymers.
Deflocculants	Acrylates, polyphosphates, lignosulfonates (Lig) or tannic acid derivates.

Other components are added to provide various specific functional characteristics, other common additives include shale inhibitor, lubricants alkalinity, loss circulation materials (LCM), control additives, defoamers and emulsifiers. Drilling fluid additives exhibit different behaviors under different drilling conditions, bentonite clay has a series problem in HPHT conditions, it start to chemically break down at temperatures as low as120 ^{o}C, increasing the drilling fluid loss into formation layers and reducing the effectiveness of cutting transport (Abdo & Haneef, 2013). Also, it has been identified that high concentration of KCl increases flocculation in rheology of WBM and increases the cutting disposal cost. Therefore, lower concentration of KCl is recommended with polymers to obtain desired rheological properties.

Nanotechnology has huge applications in different segments in oil and gas industry including but not limited to exploration, drilling, completion and work-over, production, and Enhanced Oil Recovery (EOR). They are used to produce lighter, stronger, and more corrosion-resistant structural materials in offshore drilling platforms. Nanotechnology can also be used for separation of oil and gas in the reservoir through better understanding of processes at the molecular level (Ragab & Noah, 2014). The extremely high surface area to volume ratio of nanoparticles as shown in Figure 1.1 can bring up several technical advantages for safe and economic drilling operations. Due to this fact, the amount of NPs required for any application is much less compared to conventional materials used which reduces the costs significantly.

At a recent time, outstanding efforts are taken by the petroleum institutions to formulate nano additive to the WBM to overcome standing challenges and to improve drilling performance (Riley et al., 2012). Numerous amount of nano materials in the particle size range of 1-100 nanometers has been investigated as drilling fluid additives (El-Diasty & Ragab, 2013; Ragab & Noah, 2014). Nanoparticles compared to their bulk phase materials offer many potential applications to oil and gas industry (Amanullah et al., 2011).

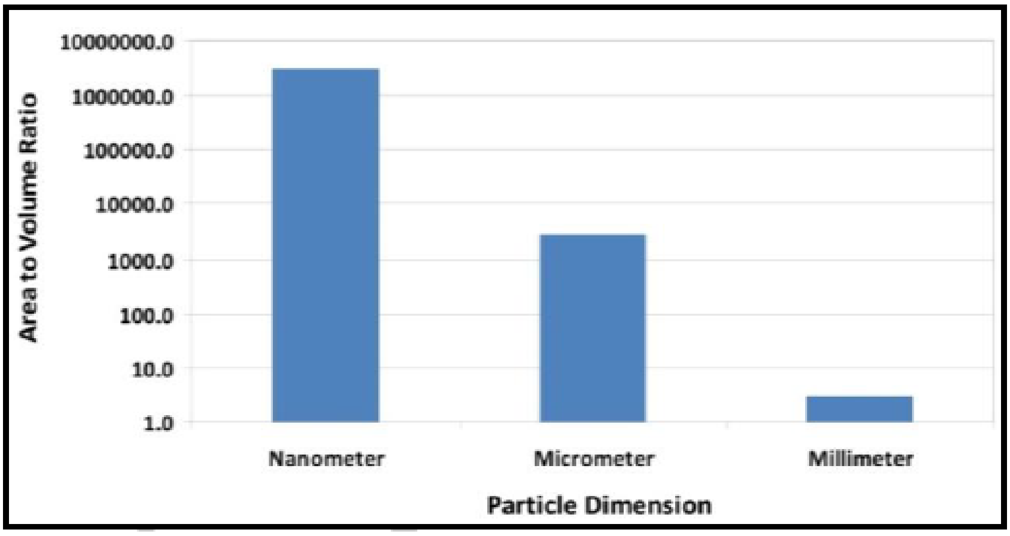

Figure 1.1 Area-to-volume ratio of the same materials volume (Amanullah et al., 2011).

The implementation of nano particles in oil and gas industry is presently facing the challenge selecting the optimum and fit-for-purpose type, size, and concentration of nanoparticles as they are chemically active and sensitive to the change down hole conditions and fluctuation of mud components behavior. Drilling fluid rheology and thermal stability can be improved with (NPs). By referring to (William, Ponmani, Samuel, Nagarajan, & Sangwai, 2014) NPs different applications in drilling mud have been reported, and they range from viscosity stabilization, prevention of loss circulation at high temperature, enhancing the carrying ability of the mud of drilled cuttings, decrease water seepage into the formation, dehydrating clay and minimizing pipe-sticking incidents. Variety of NPs have been examined for viscosity enhancement and shale inhibition characteristics of drilling mud. The most investigated NPs for drilling are nanosilica, multi-walled carbon nanotubes, graphene oxide, copper oxide and zinc oxide.

(Mody & Hale, 1993)state that the tiny size, high area of surface to volume ratio, and high surface energy of NPs empowers it to adsorb over the surface of the clay and seals its pore throats. So, shale plugging and coating can be attained with the combination of polymeric material and nanoparticle to form a nanocomposite with enhanced properties more than the properties of the individual constituent.NPs can dissipate heat due to their large surface area per unit volume and high thermal conductivity, thus improving the thermal capacity of drilling fluids (Ponmani, Nagarajan, & Sangwai, 2016; Sedaghatzadeh, Shahbazi, Ghazanfari, & Zargar, 2016; William et al., 2014).

Fluid loss takes place due to variation in pressure between the formation pressure and the wellbore fluid pressure. Thus pressure is higher in the wellbore fluid than the pressure of formation, fluid flows into the formation.Typically this phenomenon occurs during drilling, completing the well and wokover / well interventions. Differential pressures that cause loss of fluid are generated bysurge pressure in the wellbore while pulling through the whole, circulation for cleaning and conditioning the well, or by low pressure in the depleted formations occurring naturally. Losses of fluids can vary from minor to serious depending on the rate of loss. Lost circulation occurs once the lost rate exceeds the pumping power of the rig and the fluid does not return the annulus. The occurrence of lost circulation can be observed by the decrease in mud pit volume. Therefore, to avoid lost circulation from happening, prevention step which is by adding fluid loss control agent into the mud is one of the common practices (Hughes, 2006).

1.2 Problem Statement

Water based mud has difficulty in term of fluid loss, that lead to use various additives to control such issue. Basic mud containing ferric oxide NPs (3 nm and 30 nm) have been studied by(Barry, Jung, Lee, Phuoc, & Chyu, 2015; Jung et al., 2011). The results showed that the increase in concentration of NPs into bentonite suspension resulted in improving filtration properties in comparison to the base fluid. However, the effect of this type of NP was not investigated at high pressures and high temperatures. Silica NPs provided benefits as a fluid loss additive at LTLP conditions .Nanosilica has better physical plugging characteristics as well high heat capacities to form a composite with polymer materials (Sadeghalvaad & Sabbaghi, 2015). Due to the tiny sizes, nanoparticles work as a excellent bridging agents, they physically plug the nanometer-sized pore holes and prevent water loss especially in shale formations, thereby minimize wellbore instability events(Hoelscher, Young, Friedheim, & De Stefano, 2013). For the same reason, they play significant role in developing very compacted and impermeable mud cake (Contreras, Hareland, Husein, Nygaard, & Alsaba, 2014). Because of their high volume-to-volume area and very low concentration requirement, Nano WBM with capability of hydrophilic film forming on the bit surface is expected to eliminate the bit balling totally. As result of all this, is WBM with advantages of OBM, but cheaper and environmentally acceptable (El-Diasty & Ragab, 2013). Therefore to overcome this problem nanosilica and polypropylene composite based mud might be a solution for fluid loss control on account of their fair properties and functionalities, of enhanced pore plugging. Accordingly to tackle such issue, combination of hydrophobic chemically inert PP with the ability to hold off water molecules in the mud owing to its hydrophobicity and nanosilica expected to be effective in plugging the shale nano-void space.

1.3 Objectives

The aims of this research

1. To investigate PP-SiO_2 NC effect on rheological properties in WBM with different concentrations at high pressure high temperature HPHT condition.
2. To compare the effect of PP-SiO2 NC various concentrations as filtrate loss control in WBM, with the commercial fluid loss agent, PAC at HPHT condition.

1.4 Scope of Study

The scope study covered the following aspects:

1. Formulating seven muds samples; Based Mud, PAC mud with different concentrations (0.5g, 1.0g, 1.5g), and PP- SiO2 NC (0.5g, 1.0g, 1.5g)

2. Identifying the rheological properties of PP-SiO_2 NC based drilling mud, for example yield point, plastic viscosity, gel strength, and pH and comparing with those of based mud and PAC before and after hot rolling.

3. Examining the capacity of different concentrations of PP-SiO2 NC and PAC in water based mud to serve as filtration loss control at API and HPHT conditions.

1.5 Significant of study

Fluid loss is one of the crucial formation damage and gives the challenges in designing the fluids when there is high fluid loss occurs from downhole into the surface. This study is aimed to research the ability of nanosilica with polypropylene as water based mud fluid loss control. Positive outcome in this project would help to commercialize nanosilica as fluid loss control agent. This will reduce cost of drilling.

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