IMPROVE PERFORMANCE OF DIFFERENT TYPES OF DRILLING FLUIDS USING NANOMATERIALS

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ABSTRACT

Deepwater drilling in offshore operations found negative impact on the drilling fluids rheological properties when exposed to high pressure high temperature (HPHT) conditions. Hence, designing drilling fluids for drilling in deep sea and HPHT wells are major challenge. The major drilling fluid properties to ensure the success under these conditions are rheology, fluid loss, mud cake thickness and lubricity. In this study, the impact of multi-walled carbon nanotube (MWCNT) and nano metal oxides (titanium oxide, aluminium oxide and copper oxide) on the rheological properties of drilling fluid were investigated. Adding a suitable amount of nanoparticles into drilling fluid is very important because it will affect the properties and behavior of drilling fluids. Thus, the influence of different concentrations of nanoparticles on rheological properties of water-based mud (WBM), sarapar-based mud (SBM) and ester-based mud (EBM) were investigated at room temperature and aging at 250 ℉ and 16 hours. The experimental results show that the filtrate loss of the WBM is reduced around 65% and mud cake thickness is reduced about 30% in the presence of 1 g MWCNT. WBM and SBM with metal oxide also produced low filtrate loss. For example, WBM and SBM plus titanium oxide achieved more than 50% reduction in fluid loss and the mud cake thickness reduced to about 30%. However, the presence of nanoparticle in EBM resulted that no effect to filtrate loss and mud cake thickness. Furthermore, significant improvements are seen in the rheological properties such as yield point, plastic viscosity and gel strength of the WBM and SBM with the presence of metal oxide and MWCNT. Except titanium oxide, EBM with nanoparticle displayed slightly enchantment on rheological properties. Overall, the application of nanoparticles on the rheological properties of WBM and SBM delivers on great benefits compared to EBM.

ABSTRAK

Operasi penggerudian di luar pesisir menunjukkan kesan negatif terhadap sifat-sifat lumpur gerudi apabila didedahkan di bawah keadaan suhu tinggi dan tekanan tinggi. Cabaran utama untuk menggerudi di laut dalam dan telaga bertekanan tinggi dan suhu tinggi ialah formulasi lumpur gerudi yang sesuai. Sifat-sifat lumpur gerudi terdiri daripada reologi, kehilangan bendalir, ketebalan kek lumpur dan kelinciran. Dalam kajian ini, kesan kepada tiub nano karbon dinding berlapis (MWCNT) dan nano oksida logam (titanium oksida, aluminium oksida dan kuprum oksida) ke atas lumpur gerudi telah dikaji. Penambahan jumlah nanopartikal yang sesuai ke dalam lumpur gerudi amat penting kerana ia akan memberikan kesan terhadap sifat-sifat lumpur gerudi. Oleh itu, pengaruhan nanopartikal dengan kepekatan yang berbeza terhadap sifat-sifat reologi WBM, SBM dan EBM telah dikaji pada suhu bilik dan dibiarkan pada suhu 250℉ selama 16jam. Keputusan ujian menunjukkan kehilangan turasan WBM menurun kepada kira-kira 65% dan ketebalan kek lumpur menurun kepada kira-kira 30% dengan penggunaan 1 g MWCNT. WBM dan SBM dengan oksid besi juga menghasilkan kehilangan turasan yang rendah. Contohnya WBM dan SBM dengan titanium oksid menurunkan lebih 50% kehilangan bendalir dan ketebalan kek lumpur menurun kepada kira-kira 30%. Walaau bagaimanapun, penambahan butiran nano ke dalam EBM tidak memberikan kesan kepada kehilangan bendalir dan ketebalan kek lumpur. Penambahan oksid besi dan MWCNT ke dalam WBM dan SBM juga memberikan keputusan yang baik terhadap sifat-sifat lumpur seperti takat alah, kelikatan plastic dan kekuatan gel. Kecuali oksid titanium, EBM dengan butiran nano memberikan sedikit peningkatan terhadap sifat-sifat reologi. Secara keseluruhan, penggunaan butiran nano terhadap sifat-sifat reologi WBM dan SBM adalah lebih baik berbanding EBM.

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LIST OF ABBREVIATIONS

API	-	American Petroleum Institute
AV	-	Apparent Viscosity
CCVD	-	Catalytic Chemical Vapour Deposition
CNT	-	Carbon Nanotube
ES	-	Emulsion Stability
EBM	-	Ester-Based Mud
FESEM	-	Field Emission Scanning Electron Microscope
HTHP	-	High Temperature High Pressure
GBM	-	Gas Based Mud
OBM	-	Oil Based Mud
MWCNT	-	Multi-walled Carbon Nanotube
PHPA	-	Partially Hydrolyze Poly Acrylamide
PV	-	Plastic Viscosity
SBM	-	Synthetic-Based Mud
SEM	-	Scanning Electron Microscope
SWCNT	-	Single-walled Carbon Nanotube
WBM	-	Water Based Mud
YP	-	Yield Point

LIST OF SYMBOLS

μ_a	-	Apparent Viscosity, cP
μ_p	-	Plastic Viscosity, cP
E	-	Activation Energy, joules
P	-	Pressure, psi
R	-	Gas Constant, $Jmol^{-1}K^{-1}$
T	-	Temperature, ℉
Y_p	-	Yield Point, $lb/100ft^2$
τ	-	Shear Stress, Pa
$\dot{\gamma}$	-	Shear Rate, s^{-1}

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The success of a well is highly depending on the drilling fluid used during drilling and completion. The choice of the drilling fluid and its additives becomes more complex especially more products of different functions are introduced every year. 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. Drilling operations face great technical challenges with drilling problem especially in deep water. Due to drilling at deep wells will have negative impact on drilling fluids rheological properties when exposed to high pressure high temperature (HPHT) conditions.

One of the challenges related with drilling deep wells in to maintain desirable rheological properties of the drilling fluid. Many factors in deep drilling that can be highly influenced and altered the rheological performance of drilling fluids. Bartlett (1967) studied the effect of temperature on the flow properties of drilling fluids for temperature up to 320 ℉. Ali and Al-Marhoun (1990) studied the effect of three

variables, pressure, temperature and aging on the rheology of WBM. Amani and Al-Jubouri (2012) studied the effect of HPHT on viscosity of both oil-based mud and water-based muds. Based on statement, all these studies showed that alteration and changes happened in the fluid rheological properties included negative impact on rheological properties of drilling fluids. Oil-based drilling muds (OBM) are preferred for HPHT condition because of their better stability and OBM can maintain the rheological properties in such extreme condition. However, at HTHP conditions, Oakley *et al*., (2000) mentioned that drilling fluids are also likely to experience gelation, degradation of weighting materials and the breakdown of polymeric additives which act as viscosifiers, surfactants and fluid-loss additives.

Furthermore, most of the muds contain the solid particles that can cause formation damage due to poor quality of mudcake. According to Amanullah *et al*., (2011), cutting generated while drilling may produce enough micro-sized and colloidal particles to cause severe formation damage if a poor quality mudcake is deposited on the wellbore wall. Damage by solids particles invasion and difficulties in cleaning the damage have been recognized by oil and gas industry thus, prevention of formation damage should be priority rather than clear the damage (Amanullah *et al.*, 2011).

Another drilling problem is filtrate loss which occurs in the high permeability formation where the drilling fluid filters through the wall of the wellbore and invades the formation. The solid residue of the drilling fluid will deposit a layer of mud cake on the wall of the borehole. In high permeability formation, the high pressure difference caused by the drilling fluid invasion into the formation can cause the drill pipe to get stuck into the thick mud cake. This phenomenon is called differential sticking. On the other hand, drilling fluid can cause formation damage in the shale formation as a result of water hydration. Infield practise, a several type of fluid loss agent has been utilized in drilling fluid to reduce the drilling fluid loss. According to Amanullah *et al*., (2011), it is often impossible to reduce fluid loss with micro and macro type fluid loss additives due to physio-chemical and mechanical characteristics. Normal fluid loss additives with diameter in the range of 0.1-100 μm

are not effective in reducing fluid loss in the formation with pore size less than 0.1 μm such as shale.

Both technical and environmental challenges greatly escalate the cost of drilling a well. However, oil industry views this as an opportunity to develop a cost effective and environmental sustainable drilling fluid that meet the technical requirement. As a result, nanotechnology comes into interest of oil and gas industry as a candidate that offer the solution for the above challenges due to its special character.

In brief, nanotechnology is the application of very small pieces of materials at dimensions approximately 1 to 100 nanometer. Nanotechnology is science, engineering, and technology conducted at the nano-scale. Nano-particles have small sizes; these particles exhibit an enhanced effect of the mother material due to the larger surface to volume ratio. Another reason the special of nano-particles are nano scale, the statistical mechanics and quantum mechanics' effect became dominant.

Nanotechnology have been applied widely notably electronics, biomedical, material, coating, pharmaceuticals, manufacturing and telecommunication industry. It is undergoing an extensive research and development currently. However, the application of nanotechnology within oil and gas industry is still in its infancy despite its huge potential. There are huge potential to employ nanotechnology throughout the value chain of oil and gas industry including exploration, production, transportation, storage and refining. Other application of nanotechnology in oil and gas industry includes enhanced oil recovery (EOR) and reservoir monitoring (nanosensor).

The addition of nanoparticles improves the rheological, mechanical, and thermal properties of the fluid. The suspension of nanosized particles may also enhance the fluid stability and lessens the sedimentation and clogging of small

passages (Karthikeyan. *et al*., 2008). Proper used of dispersion method is very important to obtain stable suspensions. On the top of nano fluid which contain neutralizing functional group (hydroxyl) and nano-sized sulfide scavenger can reduce the problem of acid gases by generating insoluble metal sulphide precipitates (Amanullah and Al-Tahini, 2009).

1.2 Problem Statement

By using nanotechnology, it might be help to reduce or minimize the drilling problem after adding the nanoparticle into the drilling fluid. Recently, many researchers had worked on nanoparticles as additives to overcome the drilling problem such as pipe stuck, borehole instability, fluid loss, poor quality of mudcake, emulsion instability, corrosion and loss circulation. In addition, deepwater and HPHT condition will brought negative impact to rheological properties of drillings fluids. Hence, the application of nanoparticles as an additive also plays a positive role in maintains or improves the rheological performance of drilling fluids especially in HPHT conditions. (Amanullah et. al. 2011).

1.3 Objectives

The objectives of the study is to study the rheological performance on drilling fluids by adding different types of nanoparticles with different concentration.at high pressure high temperature (HPHT) conditions.

1.4 Scope of Study

The main scope of the study is to investigate the possibility of improving the performance of WBM and SBM by using nanoparticles.

The scopes of this study are:

i. To employ nanoparticles i.e MWCNT and nano metal oxide (titanium oxide, aluminium oxide and copper oxide) as an additives for WBM and SBM.
ii. To prepare nano-based mud by adding nanoparticle with concentration of 0.001 g, 0.01 g, 0.1 g and 1 g respectively.
iii. To perform the rheological properties test such as plastic viscosity, apparent viscosity, yield point and gel strength (10 sec & 10 min) for the non-aging and aging samples.
iv. To perform the filtrate loss test and measure the thickness of the mud cake in HPHT conditions.

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