ENHANCEMENT OF WATER BASED MUD PERFORMANCE USING IRON OXIDE AND POLYANIONIC CELLULOSE NANOPARTICLES

SHAIKH NIHAAL

UNIVERSITI TEKNOLOGI MALAYSIA

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SHAIKH NIHAAL

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ABSTRACT

Iron oxide and polyanionic cellulose nanoparticles (nano-PAC) have been previously used, but individually, to enhance the properties of the drilling mud. The use of iron oxide nanoparticles (IONP) showed significant enhancement in the rheology of the drilling mud while the use of nano-PAC has decreased the fluid loss. However, the use of combination of both has yet to be reported. Therefore, in this study, a mixture of both components was used to investigate its effect on the drilling mud rheological properties, fluid loss and mud cake thickness. Nano-PAC were produced using the ball milling process of PAC, while the IONP was purchased. A total of 6 types of muds were formulated: 1) base-mud, 2) mud with 3.5 wt% IONP, 3) mud with 2.5 wt% IONP and 0.2g nano-PAC, 4) mud with 1.5 wt% IONP and 0.25g nano-PAC, 5) mud with 0.5 wt% IONP and 0.3g nano-PAC and lastly, 6) mud with 0.35g nano-PAC. Generic API & HPHT fluid loss tests were carried out to measure the filtration behaviour and the mud cake thickness of the mud at ambient conditions and after hot rolling respectively. A combination of 1.5 wt% IONP and 0.25g nano-PAC in the drilling mud was found to be the most promising from the formulated mud samples as it showed consistent readings throughout the research and had an even distribution of the nanoparticles in it. By adding 1.5 wt% IONP and 0.25g nano-PAC; the density, 10-s gel strength, 10-min gel strength and the yield point increased by 2%, 23%, 6% and 11% respectively, as compared with the base mud. Whereas, the plastic viscosity and the filtrate volume decreased by 27% and 32% respectively at ambient conditions. The mud cake thickness and the pH remained the same at ambient conditions for both, the base mud and the mud with 1.5 wt% IONP and 0.25g nano-PAC. After hot rolling, the density, 10-s gel strength, 10-min gel strength and the yield point increased by 3%, 56%, 52% and 33% respectively, whereas, the filtrate volume decreased by 21%. There was no change in the mud cake thickness, pH and the plastic viscosity of both, the base mud and the mud with 1.5 wt% IONP and 0.25g nano-PAC. From the findings, it was proven that the combination of nano-PAC and IONP can enhance the drilling mud rheological properties, reduce fluid loss while maintaining the mud cake thickness, therefore has a great potential as drilling fluid additive.

ABSTRAK

Nanopartikel sel oksida besi dan polianionik (nano-PAC) sebelumnya telah digunakan, tetapi secara individu, untuk meningkatkan sifat lumpur penggerudian. Penggunaan nanopartikel besi oksida (IONP) menunjukkan peningkatan yang signifikan dalam reologi lumpur penggerudian sementara penggunaan nano-PAC telah menurunkan kehilangan bendalir. Walau bagaimanapun, penggunaan gabungan kedua-duanya masih belum dilaporkan. Oleh itu, dalam kajian ini, campuran kedua-dua komponen digunakan untuk mengkaji kesannya terhadap sifat reologi lumpur penggerudian, kehilangan bendalir dan ketebalan kek lumpur. Nano-PAC dihasilkan menggunakan proses penggilingan bola PAC, sementara IONP dibeli. Sebanyak 6 jenis lumpur dirumuskan: 1) lumpur dasar, 2) lumpur dengan 3,5% berat% IONP, 3) lumpur dengan 2.5% berat IONP dan 0.2g nano-PAC, 4) lumpur dengan 1.5% berat IONP dan 0.25 g nano-PAC, 5) lumpur dengan 0.5% berat IONP dan 0.3g nano-PAC dan terakhir, 6) lumpur dengan 0.35g nano-PAC. Uji kehilangan cecair generik API & HPHT dilakukan untuk mengukur tingkah laku penapisan dan ketebalan kek lapis lumpur pada keadaan sekitar dan selepas penggulungan panas masing-masing. Gabungan 1.5% berat IONP dan 0.25g nano-PAC dalam lumpur penggerudian didapati merupakan kepekatan yang paling menjanjikan kerana ia menunjukkan pembacaan yang konsisten sepanjang penyelidikan dan pengedaran nanopartikel di dalamnya. Dengan menambahkan 1.5 wt% IONP dan 0.25g nano-PAC; ketumpatan, kekuatan gel 10-s, kekuatan gel 10-minit dan titik hasil masing-masing meningkat sebanyak 2%, 23%, 6% dan 11%, berbanding dengan lumpur dasar. Manakala, kelikatan plastik dan isipadu turas masing-masing menurun sebanyak 27% dan 32% pada keadaan persekitaran. Ketebalan kek lapis dan pH tetap sama pada keadaan persekitaran untuk keduanya, lumpur dasar dan lumpur dengan 1.5% berat IONP dan 0.25g nano-PAC. Selepas penggulungan panas, ketumpatan, kekuatan gel 10-s, kekuatan gel 10-minit dan titik hasil masing-masing meningkat sebanyak 3%, 56%, 52% dan 33%, sedangkan, isipadu turas menurun sebanyak 21%. Tidak ada perubahan ketebalan kek lapis, pH dan kelikatan plastik keduanya, lumpur dasar dan lumpur dengan IONP 1.5% berat dan nano-PAC 0.25g. Dari hasil penemuan, terbukti bahawa gabungan nano-PAC dan IONP dapat meningkatkan sifat reologi lumpur penggerudian, mengurangkan kehilangan bendalir sambil mengekalkan ketebalan kek lumpur, oleh itu berpotensi besar sebagai aditif bor penggerudian.

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IONP	-	Iron Oxide Nanoparticles
PAC	-	Polyanionic Cellulose
Nano-PAC	-	Polyanionic Cellulose Nanoparticles

CHAPTER 1

INTRODUCTION

1.1 Problem Background

1.1.1 Rheology and Fluid Loss Control

The rheological properties of the drilling fluid should be tracked and regulated in the well. Based on this information, frictional loss can be predicted accurately. As the drilling fluid flows through the well, it is affected by temperature, pressure, time, etc., and all these parameters result in a significant change in the properties of the drilling fluid. Thus, making it difficult to track and regulate its rheological properties. (Vryzas et al., 2016)

In order to get the rheology right to its smallest detail, a deep understanding is required of the drilling fluid, including the contribution of the related microstructure mechanisms on the properties of the flow. (Vryzas et al., 2015)

Fluid loss is another aspect that needs to be eliminated in order to facilitate safe and rather efficient drilling. When the mud filtrate enters the newly exposed formation, it causes damage to the formation. This results in expensive treatments and also loss of output. This issue has been a part of oil and gas sector since the very beginning, affecting the output. (Vryzas et al., 2017)

Fluid loss occurs when there is a normal differential pressure between wellbore and reservoir. Most well are drilled over-balanced for safety purposes (with greater wellbore pressures than formation fluid pressures). Mud particles accumulate and form a mud cake on the formation. A thin and impermeable mud cake and low fluid loss is desired to lessen the damage caused by formation. (Mahmoud et al., 2016)

Additives also play a crucial role in the composition of drilling fluid. Based on the type of performance desired from the drilling fluid and the problems faced during

drilling, specific additives can be added. The additives must be reliable and help conduct the drilling process efficiently. (Friedheim et al., 2012; Hoelscher et al., 2013; Taha et al., 2015)

1.1.2 Use of Iron Oxide Nanoparticles in Drilling Fluid

IONP has been a new addition into the drilling mud to enhance its properties. Although the use of IONP has not been on the field yet, it is believed to have a great amount of potential for the future of drilling. Various experiments have been carried out using IONP on a laboratory scale for both water-based and oil-based mud, and prominent enhancements were observed during these experiments by many researchers.

IONP were blended with water-based mud to study its effect on the water-based mud's performance. The following results were obtained by (Jung et al., 2011; Nwaoji et al., 2013; Vryzas et al., 2015; Vryzas et al., 2014; Vryzas et al., 2015):

1. Reduction in fluid loss
2. Increased yield stress and viscosity
3. Smaller thickness of mud cake
4. Increased fracture pressure.

1.1.3 Use of Nano-PAC in drilling fluid

PAC is one of the popular additives being increasingly considered for easing the challenges associated with borehole drilling mechanisms. PAC is basically a technical grade, low viscosity, and dispersible additive. Chemically, it is a Polyanionic Cellulose compound. It reduces the API filtration rate through minimum enhancement in viscosity with respect to aqueous drilling fluids.

Polyanionic Cellulose nanoparticles were blended with water-based mud to study its effect on the water-based mud's performance. The following results were obtained by (Fereydouni et al., 2012):

1. Reduction in fluid loss

2. Smaller thickness of mud cake

1.2 Problem Statement

It is almost certain that problems will occur while drilling a well, even in very carefully planned wells. The general causes of drilling fluid loss from boreholes to the surrounding earth formations is due to natural fractures in the rocks, induced fractures when pressure in drilling fluid exceeds fracture pressure of the formation, highly permeable formations. Rheology also plays a major role in the success of the drilling fluid. Therefore, the best possible rheology must be assigned to the drilling fluid, which is a pretty tedious task.

From previous studies, it was found that the advantage of the mentioned nanoparticle, iron oxide also has disadvantage in fluid loss when used in excess amounts. Knowing that PAC is a good fluid loss agent but PAC alone will not make much of a difference. Therefore, in this study it is proposed that mixing the iron oxide and Nano-PAC in certain amounts will enhance the mud properties, as well as the fluid loss. Standard API & HPHT fluid loss tests were carried out along with rheological, density and pH measurements at ambient conditions and after hot rolling.

1.3 Proposed Solution & Hypothesis

i. Mixing both IONP and nano-PAC together in the drilling fluid could further increase the rheological properties and decrease fluid loss.
ii. It is predicted that the introduction of IONP and nano-PAC will increase and enhance the rheological properties of the drilling mud.
iii. It is also predicted that the nanoparticles will plug the opening between them and the pore. Thus, reducing the fluid loss further.

1.4 Objectives

i. To examine the effect of IONP and nano-PAC on the rheological properties and fluid loss of the drilling mud.

ii. To determine the best percentage of the IONP and nano-PAC from the formulated mud samples which gives most efficient rheological properties and fluid loss results.

1.5 Scope

i. Ball milling the PAC to get Nano-PAC range.

ii. Preparing 6 types of the mud which are:

- base-mud,
- mud with 3.5 wt% IONP,
- mud with 2.5 wt% IONP and 0.2g Nano-PAC,
- mud with 1.5 wt% IONP and 0.25g Nano-PAC,
- mud with 0.5 wt% IONP and 0.3g Nano-PAC,
- mud with 0.35g Nano-PAC

iii. Performing the density, rheological and pH measurements before and after hot rolling.

iv. Determining the fluid loss for the above-mentioned mud types, before and after hot rolling (standard API & HPHT).

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