Performance Evaluation of Surfactant Enhanced Nanomaterial as Efficient Water Based Mud Additive

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ABSTRACT

Increasing world's demand of hydrocarbon and recent exploration into deepwater reservoir or complex formation causes stability and effectiveness of conventional drilling fluids to be affected as it tends to undergo deterioration such as gelation, degradation, and breakdown of polymeric additives under High Pressure and High Temperature (HPHT) condition. The emergence of nanotechnology has promise high efficient drilling fluids as the nanoparticles adopt well with a wide range of operating conditions. Yet, the stability of nanoparticles in aqueous phase still a major concern due to reagglomeration effect even after high mechanical shearing. Applying electrostatic repulsion force in nanofluid believed to increase dispersion stability. Relatively, surfactant based dispersion is preferred where nanosilica as a negatively charged nanoparticle dispersed in an anionic surfactant known as Sodium Dodecyl Sulphate, SDS to increase electrostatic repulsion between negatively charged molecules for higher stability. Thus, this study is aim to investigate the performance of nanoparticle in presence of surfactant in water based mud in comparison with ultrasonic dispersed nanofluid mud and conventional Polyanionic Cellulose, PAC mud. Nanosilica has better filtration properties and been used as fluid loss control additive in various experiments especially in High Pressure and High Temperature environment. The methodology of this study initially focused into stability investigation of surfactant enhanced nanofluid by measuring the zeta potential value followed by performance evaluation of nanosilica drilling fluid in optimum concentration of SDS by analysing rheological and filtration properties in both ambient and HPHT condition. Experimental analysis shows that surfactant enhanced nano drilling fluid shows higher zeta potential value and exhibit higher dispersion and stability compared to non-surfactant nano drilling fluid and PAC mud. Thus, it shows better rheological and filtration properties especially at HPHT compared to conventional mud. Surfactant added nano drilling fluid able to control fluid loss around 20-30%, reduce mud cake thickness about 25% compared to PAC mud in HPHT condition. The completion of this study promised better nano drilling fluid formulation for efficient and smooth drilling operation by reduced rig time and cost involved.

ABSTRAK

Bendalir penggerudian mempunyai banyak fungsi dalam proses penggerudian termasuk penghapusan keratan, pelinciran, penyejukan bit, meningkatkan kestabilan telaga, dan mencegah kehilangan air antara lubang bor dan resebor. Peningkatan permintaan hidrokarbon dunia menyebabkan eksplorasi baru tertumpu kepada permukaan muka bumi yang kompleks. Ini menyebabkan kestabilan dan keberkesanan lumpur penggerudian konvensional terjejas kerana ia cenderung mengalami kemerosotan seperti gelation dan degradasi polimer di bawah keadaan tekanan dan suhu tertinggi. Kewujudan nanoteknologi telah menjanjikan cecair penggerudian yang cekap kerana kemampuan sifat pisiokimianya. Walau bagaimanapun, kestabilan nanopartikel dalam fasa cecair masih menjadi masalah utama kerana kesan reagglomerasi walaupun telah dilarutkan dalam tekanan mekanikal yang tinggi seperti ultrasonik. Oleh itu, kajian ini bertujuan untuk mengkaji prestasi lumpur nanopartikel yang dilarutkan dengan menggunakan surfaktan berbanding cara larutan ultrasonik. Hasil analisis telah digunakan untuk dibandingkan dengan lumpur selulosa polanionik konvensional (PAC). Nanosilica sebagai nanopartikel bercas negatif telah dilarutkan dalam surfaktan anionik yang dikenali sebagai Sodium Dodecyl Sulphate, SDS untuk meningkatkan penolakan antara molekul bercas negatif untuk kestabilan yang lebih tinggi. Nanosilica mempunyai sifat penapisan yang lebih baik dan boleh digunakan untuk mengawal kehilangan air. Metodologi kajian ini pada mulanya tertumpu kepada penyiasatan kestabilan bendalir nano surfaktan dengan menggunakan potensi zeta, diikuti dengan penilaian prestasi riologi dan kehilangan filterasi cecair penggerudian. Analisis Penapisan API telah dijalankan untuk mengkaji sifat lumpur nanosilica sebagai aditif untuk mengawal cecair penggerudian di suhu normal dan juga dibawah tekanan tertinggi dan suhu tertinggi. Hasil kajian menunjukan lumpur nanosilica yang dilarutkan dengan surfaktan mempunya sifat riologi yang lebih baik dan mampu mengawal kehilangan air secara efektif berbanding lumpur nanosilika larutan ulrasonik dan lumpur konvensional. Penyiapan kajian ini akan menjanjikan kesimpulan lumpur nano yang lebih baik untuk operasi penggerudian yang cekap dan lancar dengan penjimatan masa dan kos penggerudian.

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LIST OF ABBREVIATIONS

API	-	American Petroleum Institute
ECD	-	Equivalent Circulating Density
HPHT	-	High Pressure High Temperature
KCl	-	Potassium Chloride
LCM	-	Loss Circulating Material
LPLT	-	Low Pressure Low Temperature
Min	-	Minutes
mm	-	millimetre
NP	-	Nanoparticles
OBM	-	Oil Based Mud
PAC	-	Polyanionic Cellulose
PSO	-	Particle Swarm Optimization
SBM	-	Synthetic Based Mud
SDS	-	Sodium Dodecyl Sulphate
WBM	-	Water Based Mud

LIST OF SYMBOLS

°C	-	Degree Celsius
F	-	Force
v	-	Velocity
p	-	Pressure
>	-	More Than
<	-	Less than
Wt %	-	Weight Percentage
μ	-	Viscosity

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Drilling mud has evolved enormously since 1901, when first major petroleum discovery using rotary drilling and circulating mud was made at spindletop, Texas USA. The spindletop mud is simply water made viscous by hydrating clay cuttings. The fluid used was just dirt and water till 1920s (Al-Yasri et al., 2015). Since then some improvements have been made to use barite for weight control and bentonite for hole cleaning and suspension purpose. In 1930, Baroid sales company, the first mud sales and Service Company was formed. The first mud product designed to solve various drilling problems including viscosity and fluid loss control phenomenon. Consequently, mud products and mud companies expanded greatly after World War II. Today muds are complex mixtures of bentonite, polymers, thinners, barite and a host of other ingredients that accomplish several task and problems in drilling industry.

Drilling fluid can be defined based on its function, composition and complexity. The American Petroleum Institute (API) defines it as circulating fluid employed to save any or all of the various responsibilities involved in drilling operations of rotary drilling (Al-Yasri et al., 2015). It is used to remove cuttings, stabilise wellbore from damage, cool and lubricate drill bit and control formation pressure. However, there are still several limitations in drilling fluids that reduce drilling performance. Some types of drilling fluids are not suitable to use for certain reservoir conditions, costly and harm the environments. Various properties of drilling fluid need to be focused for ultimate performance and success of the drilling operation (Gokul et al., 2017).

As such, lost circulation of drilling fluid has been a growing challenge to oil and gas industry. As demand for oil and gas has rapidly increasing the focus shifts into exploration of new hydrocarbon fields which often involved complex subsurface environments and harsh condition (Vipulanandan & Mohamed, 2018). This causes severe loss of drilling fluid due to degradation or alteration which adversely affects the drilling activities (Amanullah, 2016). Schlumberger defined fluid loss as leakage of liquid phase of drilling fluid, slurry or treatment fluid containing solid particles into the formation matrix which could cause blowout, kick or collapse. This subsequently leads to excessive cost of drilling due to mud loss, increasing rig time and extensive formation damage. Drilling fluid supposed to be circulated down to the bottom hole and come back to the surface for cutting transport and cooling the bit.

However, when lost circulation occurs, drilling fluids are lost and Loss Circulation Materials (LCM) needed to be added to the mud to avoid further fluid loss (Mansour & Teleghani, 2018). LCM is a material that seals the fractures and minimizes mud loss into formation. Commonly used materials include fibrous materials, granular materials and flake like materials. However, there are several limitations on LCM or additive such as Xanthan Gum or Starch which often degrade at HPHT environment (Al-Yasiri et al, 2015). Although there are many researches are ongoing most of the fluid loss control agent failed to control fluid loss into formation efficiently.

Nanotechnology has come to the forefront research to design smart fluids to enhance filtration performance and to provide better rheological behaviour (Yadav et al., 2017). It has better physio-chemical properties with particle size of 1-100nm and high surface to volume ratio compared to micro or macro chemicals additives. Nanoparticles have better thermal stability for HPHT conditions and able to serve as bridging agents in fluid lost system to control loss circulation (Krishnan et al., 2016). Silica, Iron Oxide, Copper Oxide, Zinc Oxide, Graphene Oxide, Aluminosilicate Clay Hybrid, Multi walled Carbon Nanotube and Titanium Oxide are some of the nanoparticles that have been involved in drilling fluid enhancement studies (Vryzas & Kelessidis, 2017).

Apart from these technical advantages, nanoparticles have great benefits on economic and environment too. Economically, usage of nanoparticles over expensive additives reduces drilling fluid cost. Nanofluid enhances oil recovery process due to its ability to reach deep challenge formations. Non-productive time could be reduced by eliminating further mitigation process of fluid loss at earlier stages, thus reduces rig time and cost. Environmentally, Water Based Mud (WBM) is preferred over Oil Based Mud (OBM) as base for additive (Abduo et al., 2016). Successful application of nanoparticles in water based mud could reduce oil based mud usage and this reduces environmental impact especially by eliminating wastage for disposal (Amanullah, 2016).

While most of the nano drilling, fluid investigations carried out in lab scale, there are few studies have been tested in real conditions. Borisove et al., 2015 have conducted field test on application of nanoparticle based invert emulsion drilling fluids. The test shows nano drilling fluid can significantly reduce fluid loss and produce thinner filter cake compared to LCM alone. This study proven that the total mud losses were reduced by 22-34% in the presence of 0.5 wt % calcium nanoparticles which agrees with what was obtained in lab during preliminary studies. In another field study, application of nanofluid containing a blend of proprietary surfactants engineered with nano graphene been investigated. The nano drilling fluid was tested in HPHT onshore well and results showed 30% of fluid loss control compared to conventional mud (Taha & Lee, 2015).

The nano drilling fluid able to bring a revolution in an oil and gas industry as it can fulfil the specific needs of new drilling technologies. There are several researchers currently working on scaling up the synthesis of various types of nanoparticles in order to render the process economically viable so that it can be used in oil recovery process. Yet, there is a need to overcome some technical challenges on efficiency of nanoparticles in drilling fluid application such as dispersion stability, field scale applications and compatibility with API procedures and specifications.

1.2 Problem Statement

The choice and design of drilling mud and additives becomes more challenging when exploration focused into complex subsurface geological formation as this will influence drilling fluids rheological and filtration properties (Amani et al, 2016). Currently used Lost Control Material (LCM) , xanthan gum and starch has several limitations to control fluid lost efficiently as some will degrade at HPHT condition (Ettehadi *et al.,* 2018). Therefore, nanoparticles application has been gaining attention worldwide due to better physiochemical properties even at HPHT (Nurazwan & aslam, 2015).

However, there are several limitations on nanoparticles to be used as efficient fluid loss control material as dispersion stability remains a major technical challenge. Process used to disperse nanoparticles in liquid is another critical factor for effective dispersion (Vryzas & Kelessidis, 2017). Studies show even after high shearing of nanoparticles using various mechanical methods such as ultrasonic bath, magnetic sheerer and homogenizers they tend to re-agglomerate due to strong van der waals attractive forces (Vryzas & Kelessidis, 2017). This limits their advantage of stemming from their high surface area as it is subjected to reduction in higher surface area over volume ratio to form stable dispersion.

Different strategies have been reported to yield homogenous and stable dispersion of nanoparticles. However, very little studies have been conducted to further investigate on re-agglomeration of nanoparticle after the energy supplied by mechanical or ultrasonication is exhausted especially in application of surfactant enhanced nano drilling fluid in order to enhance stability. It is reported that introduction of repulsive forces in terms of steric, electrostatic or electrosteric able to decrease agglomeration and will ensure stability (Paramashivaiah & Rajashekar, 2016). It is proven that introduction of chemical method of surface functionalization to improve chemical compatibility with base fluids using surfactants can improve wetting or adhesion characteristics and reduce tendency to reagglomerate in continuous phase solvents (Paramashivaiah & Rajashekar, 2016).

Therefore, new approach of using surfactant to enhance electrostatic repulsion between particles is being focused in order to produce effective dispersion system. This study focus into Sodium Dodecyl Sulphate (SDS), as an anionic surfactant which is proven to enhance stable dispersion in Nanosilica (Vatanprasat *et al.*,2018). Nanosilica is commonly used nanoparticles because of their low cost fabrication and cost effective surface modification. It is expected that electrical double layer formed at the interface between a nanosilica and electrolyte will help the anionic surfactant to approach and cover the surface of nanoparticles that have negative charges. The hydrophobic tails of surfactant will generate a steric repulsive force and prevent the nanoparticles aggregation and dispersion would remain stable (Azadgoleh et al., 2014). This stability will enhance nanoparticles dispersion in water based mud, thus high surface area over volume ration will be retained to plug and seal formation hence this helps to control filtrate lost when introduced into drilling mud.

1.3 Objective of Study

The main objective of this research is to evaluate the performance of surfactant enhanced nanoparticle as efficient fluid Lost Control Material (LCM) as follow: -

a) To characterize stability of surfactant enhanced nanoparticle water based mud at optimum nanosilica concentration.

b) To determine rheological properties of surfactant added and non-added nanoparticle water based mud in comparison with conventional mud at ambient and High Pressure and High Temperature (HPHT) condition.

c) To evaluate efficiency of filtrate properties in surfactant added and non-added nanomaterial drilling fluid.

1.4 Scope of Study

(a) Conducting laboratory experiments on stability dispersion of nanosilica in anionic surfactant, Sodium Dodecyl Sulphate (SDS) in concentration range of 3%, 4 %, 5%, 6% and 7% by measuring zeta potential value.

(b) Evaluating rheological properties of surfactant added and non-added nanosilica water based mud in comparison with conventional water based mud, HydroPacR by analysing Plastic Viscosity (PV), Yield Point (YP) and gel Strength at ambient (100psi) and after hot rolling (250°F & 500psi) condition.

(c) Conducting API Filter Press Test (for filtrate lost volume) at ambient and after hot rolling temperature.

1.5 Rationale of Study

The main concern of this research is to evaluate efficiency of surfactant enhanced nanoparticle to be used in drilling fluid to enhance rheological and filtrate properties. This is to formulate new drilling mud to be used in drilling industry to eliminate dispersion limitation risen from commonly used nano, micro or macro polymers additives.

1.6 Significance of Study

The significance of this study is to reveal the efficiency of surfactant enhanced nanoparticle as driling fluid lost control material. Surfactant and nanoparticle are widely been used in various industries hence positive results of this study may lead to commercialization of newly formulated mud to be used in petroleum industry to reduce lost circulation, cost and rig time involved in drilling.

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