STUDY OF NANOMATERIALS AND GLASS BEADS ON RHEOLOGICAL PROPERTIES AND LUBRICITY OF WATER BASED MUD

NORASYIKIN ZOLKIFILE

UNIVERSITI TEKNOLOGI MALAYSIA

STUDY OF NANOMATERIALS AND GLASS BEADS ON RHEOLOGICAL PROPERTIES AND LUBRICITY OF WATER BASED MUD

NORASYIKIN BINTI ZOLKIFILE

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Science (Petroleum Engineering)

Faculty of Petroleum and Renewable Energy Engineering
Universiti Teknologi Malaysia

JANUARY 2013

ACKNOWLEDGEMENT

In conducting this study, I was in contact with many people, researchers, academicians and practitioners. Alhamdulillah, for the Almighty of Allah, with His greatness and bless, I had successfully completed this thesis with full of strength, determination and positive thought.

In particular, I would like to thank to my honorable supervisor Assoc. Prof. Abdul Razak Ismail, for the encouragement, guidance, critics and friendship. I sincerely hope that in the near future this report may have some value for further study. I am also very grateful to Prof. Salasiah Endud for her advices and cooperation on nanomaterials knowledge.

Besides, I would like to express my gratitude to the technicians of Drilling Laboratory, Mr. Othman Adon, Ms. Hasanah Husin and those who contributed their favor, during the entire period of pursuing my master degree in UTM.

My sincere appreciation also extends to my parent and all my friends, who have provided the assistances at various occasions. Their views and tips are useful indeed. Thank you very much for everything.

ABSTRACT

Torque and drag arises from the frictional forces which occur between the wellbore and the rotating drill string. Among the method to reduce torque and drag is by using lubricant. Water based mud (WBM) produced coefficient of friction (CoF) higher than oil based mud (OBM) and synthetic based mud (SBM). However, due to the environmental concerns, the use of OBM and SBM are restricted that caused the industry seeking for ways to improve lubricity of WBM. In this study, Multi Walled Carbon Nanotubes (MWCNTs), nanosilica and glass beads with different sizes 90-150 µm and 250-425 µm were used as lubricants. This study focused on the effect of different concentration of MWCNTs, nanosilica and glass beads on the mud rheological properties and lubricity of WBM. The CoF for mud without nanomaterials and glass beads is 0.238. The optimum concentration of glass beads about 4 ppb into the mud gives lower CoF value with torque reduction up to 30%. A finer glass bead gives the best performance in improving the lubricity of drilling fluid compare to coarse glass beads. The finding shows that the addition of 0.01 ppb of nanomaterials contributed to the optimum torque reduction up to 45%. In general, the addition of nanomaterials and glass beads at optimum concentration shows the reduction on CoF. Hence, the addition of these lubricants in the WBM also gives some improvement in the mud rheological properties.

ABSTRAK

Daya kilas dan daya seret berpunca daripada daya geseran antara lubang telaga dengan rentetan gerudi yang berputar. Antara kaedah yang digunakan untuk mengurangkan masalah ini ialah dengan menggunakan pelincir. Lumpur asas air (WBM) mempunyai pekali geseran (CoF) yang lebih tinggi berbanding lumpur berasaskan minyak (OBM) dan lumpur berasaskan sintetik (SBM). Walau bagaimanapun, demi menjaga alam sekitar, penggunaan OBM dan SBM menjadi terhad yang menyebabkan industri mencari jalan untuk meningkatkan daya pelinciran WBM. Dalam kajian ini, MWCNTs, nanosilika dan butiran kaca dengan saiz yang berbeza iaitu 90-150 μm dan 250-425 μm telah digunakan sebagai pelincir. Kajian ini menumpukan untuk menganalisis nilai kepekatan MWCNTs, nanosilika dan butiran kaca pada sifat reologi lumpur dan perbandingan tahap kelinciran pada WBM. Nilai CoF untuk sampel tanpa nanopartikel dan butiran kaca adalah sebanyak 0.238. Penambahan kepekatan optima butiran kaca sebanyak 4 ppb memberi nilai CoF yang rendah dengan penurunan nilai pekali geseran sebanyak 30%. Butiran kaca bersaiz kecil memberikan prestasi yang lebih baik dalam meningkatkan tahap kelinciran berbanding butiran kaca bersaiz besar. Keputusan mendapati, penambahan kepekatan nanopartikel sebanyak 0.01 ppb menyumbang kepada penurunan nilai pekali geseran sehingga 45%. Secara umum, penambahan nanopartikel dan butiran kaca pada kepekatan optima menunjukkan pengurangan pada COF. Oleh itu, penambahan pelincir pada WBM memberi kesan yang baik terhadap beberapa pembaikan dalam sifat reologi lumpur.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

WBM	-	Water Based Mud
OBM	-	Oil Based Mud
SBM	-	Synthetic Based Mud
API	-	American Petroleum Institute
CoF	-	Coefficient of Friction
ERD	-	Extended Reach Drilling
TVD	-	True Vertical Depth
CCVD	-	Catalytic Chemical Vapour Deposition
Pac UL	-	Hydro Pac UL
FESEM	-	Field Emission Scanning Electron Microscopy
TEM	-	Tomography Electron Microscopic
MWCNTs	-	Multi Walled Carbon Nanotubes
SWCNTs	-	Single Walled Carbon Nanotubes
ppb	-	Part per Billion
PHPA	-	Partially Hydrolyze Poly Acrylamide
PV	-	Plastic Viscosity
LEM		Lubricity Evaluation Monitor
HTHP		High Temperature High Pressure
KOP		Kick of Point
HD		Horizontal Displacement

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Directional drilling and extended reach drilling have been used widely since the world's constraints need of crude oil where the operators keep thinking the ways to produce the hydrocarbon up to the surface. Challenges to maximize the full potential from maturing fields to meet today's ever increasing production targets has seen a warranted reappearance in Extended Reach Drilling (ERD) in many locations worldwide. Directional drilling is a process of directing the wellbore along some trajectory to a predetermined target. ERD has evolved from a simple directional drilling to horizontal, lateral, and multi lateral step outs. ERD includes both directional and horizontal well departures and total vertical depth to deviation ratios beyond the conventional experience of a particular field (Schamp *et. al*. 2006).

Apart from that, the torque and drag becoming the major issues in succeeding the extended reach drilling. Torque and drag arises from the frictional forces which occur between the well bore and tubular, and the bit/ stabilizer. The frictional forces are dependent upon the coefficient of friction and contact loads between two surfaces. As a solution, the management of torque and drag become crucial part of both well operations.

Analysis of torque and drag from historic well has indicated that friction factors can be simplistically grouped based on the type of mud (i.e., mineral oil, synthetic oil or water based) and the type of surfaces in contact i.e. cased hole or open hole (Aston *et. al*. 1998). Finding the best technique for torque and drag reduction becomes critical as more fields require extended reach drilling. Many different techniques have been used to reduce torque and drag. One of the methods is using lubricants, either chemical liquid or solid particles.

In the last few years, increasingly strict environmental legislation imposed in many parts of the world has changed the choice of chemistries utilised for water based fluid lubricants. However, the use of water based mud (WBM) for drilling operation could be unfavourable because of their high coefficient of friction (CoF). Torque and drag arises from the frictional forces which occur between the wellbore and drill bit. Oil based mud (OBM) and synthetic based mud (SBM) generally produces CoF that are lower and better wellbore stabilizing characteristic than those produced by WBM but it can cause significant environmental damage.

Instead of using OBM and SBM is severely limited by environmental concerns, lubricants are often used to reduce the inherent CoF of a drilling fluid. These indicate that a wide range of lubricants types can be effective in WBM. Lack of lubricant during drilling will cause higher friction between the drill bit with the borehole, thus increase the power usage to rotate the bit and will increase the drilling operation cost.

Due to totally different and highly enhanced physio chemical, electrical, thermal, hydrodynamic properties and interaction potential of nanomaterials compared to their parent materials, the nanomaterial are considered to be the most promising material of choice for smart fluid design for oil and gas field application. Water based nano fluids developed using several commercial nano materials to overcome the challenges associated with conventional drilling fluids. In addition, the natures of nanomaterial which is very fine but have very high specific surface area with enormous area

interactions just need very low concentration of nanomaterials to provide great enhancement in fluid properties (Amanullah *et. al*. 2011).

Mud lubricity also can be improved by using lubricants. These lubricants can be solids or liquids. Solid lubricants such as beads act much like ball bearing. These materials interfere with the contact surfaces without bonding to them. Because they do not bond, the performance of these lubricants is usually independent of mud type. For the liquid lubricants, it form a film that is thick enough to mask surface, their performance tends to depend on their concentration since they compete with either surface active component in the drilling mud (Bloemendal, 1978).

Research is currently aimed to developing environmentally safe and non toxic, so WBM will have better lubricant and better hole cleaning properties with adding small amount of lubricant. There are many parameters have been studies in order to produce minimum CoF value in drilling operations such as the different types and sizes of additional lubricant into based mud and rate of concentration.

1.2 Problem Statement

WBM produce higher CoF compared to OBM and SBM and generally produce increase the wear rates in the wellbore. However, the advantage of WBM is due to low toxicity compared to OBM. Lubricants are used to reduce the friction which is by mixing with the drilling fluids (Growcock *et. al*. 1998). CoF is one of the drag forces which is the force of friction between the drill string and wellbore. Lower CoF denotes good lubricity of a fluid (Kercheville, 1986). The drag force can cause several problems such as energy losses to the wall due to excessive pump pressure, limited flow and excessive stress on downhole equipment.

Nanotechnology seems to have a great potential in oil industry especially in drilling application. Many researches on nano based drilling fluid have done to deal with wellbore problems such are wellbore instability, emulsion instability and HTHP applications. Recent research have demonstrated that, nanofluids have attractive properties for application where heat transfer, drag reduction, binding ability or sand consolidation, gel formation, wettability alteration, and corrosive control is of interest (Phuoc *et. al.* 2007).

The potential to make tailored made particles with custom made behavior is also going to play an important role in superior nano based fluid formulation. Hence, the application of nano-based fluid additives in formulating high performance water based mud systems has the potential to overcome the current as well as future technical challenges especially in HTHP condition (Amanullah *et. al.* 2011).

Friction reducers can be divided into two types: liquids and solid particles. One solid lubricant is treated graphite powder where the graphite has a lamellar structure whose planes are coupled by weak van der Waal bonds. When expose to tension, these layers part and reduce the friction. Beads have been applied to reduce friction that functioned as a ball bearing. Large polymer beads are already available commercially for use as friction reducers in drilling mud. The glass beads are chemically inert and do not affect the mud properties, except a negligible increase in viscosity and very slight decrease in 10 minute gel. Liquid lubricants, form a film that is thick enough to mask surface roughness and strong enough to withstand high compression forces (Skalle *et. al.*1999).

The lubricant used in this experiment is solid lubricants, namely glass beads, nanosilica and multi walled carbon nanotubes (MWCNTs). Glass beads move to produce a planar ball or roller bearing effect in the mud to keep the metal to metal or metal to rock interface from occurring (Schamp *et. al*. 2006). Besides, the solids movement minimizes the frictional forces between them. Thus, this research work was conducted to examine the effect of glass beads size and concentration on the lubricity of

water based mud. Besides that, the friction reduction will be reducing by adding the nanomaterials like nanosilica and MWCNTs as a lubricant. It is believed that nanomaterials can produce lower value of coefficient of friction even it is used with only low concentration. However, there is no longer an experiment conducted to determine the coefficient of friction by using these nanomaterials.

1.3 Objectives of Study:

The objectives of the study are as follows:

1. To determine the effect of nanomaterials and glass beads on drilling fluid properties.
2. To evaluate the effect of nanomaterials and glass beads on the lubricity of water based mud.

1.4 Scopes of Study:

The scopes of study are as follows:

1. Preparation of water based mud as the base mud, and mud with nanomaterials and glass beads.
2. Measurement of drilling fluid properties.
3. Determine the coefficient of friction (CoF) of base mud and mud with nanomaterials and glass beads for comparison.
4. Evaluate the effect of different concentrations of nanomaterials and glass beads used in drilling fluids to the lubricity.
5. Comparison of the different size of glass beads to be used in the mud.

REFERENCES

Abouzar, M.P. (2008). Using Nanoparticles to Decrease Differential Pipe Sticking and Its Feasibility in Iranian Oil Fields. *Oil and Gas Business.*

Amanullah, M., Ashraf, M. and Al- Tahini (2009). Nano- Technology- Its Significance in Smart Fluid Development and Gas Field Applications. *Saudi Arabia Technical Symposium and Exhibition*. Al- Khobar, Saudi Arabia, Society Petroleum Engineers.

Amanullah, M. and Zias, A. A. (2010). Preliminary Test Results of a Water based Nanofluid. 8th International Conference and Exhibition on Chemisrty in Industry. 18-20 October. Manama, Bahrain.

Amanullah, M., Al-Arfaj M. K. et al (2011). Preliminary Test Results of Nano- based Drilling Fluids for Oil and Gas Field Application. *Drilling Conference and Exhibition.* 1-3 march. Amsterdam, Netherlands.

American Petroleum Institute (2003). *American Petroleum Institute-Recommended practices for Field Testing Water based Drilling Fluids. API-RP-13B-1, Third Edition.*

Apakele, A.S., A.A. Al- majed, et al. (2012). State of the Art and Future Trend of Drilling: An Experimental Study. *Latin American and Carribean Petroleum Engineering Conferences*. 16-18 April. Mexico City, Mexico, Society of Petroleum Engineers.

Aston, M.S., Hearn, P.J and McGhee, G., BP Exploration (1998). Techniques for Solving Torque and Drag Problems in Todays Drilling Environment. *SPE Annual Technical Conference and Exhibiton*. New Orleans, Louisiana, 27-30 September .

Binks, B.P. and Whitby, C.P. (2005). Nanoparticle Silica- Stabilised Oil-in-Water Emulsions: Improving Emulsion Stability. *Colloids and Surfaces A: Physicochemical and Enginnering Aspects*. 253. 105-115.

Bloemendal, J.W., CeBo Internatinal (1978). Recent Developments in Drilling Fluid Technology.*Offshore South East Asia Conference*. 21-24 February.

Brister, Ray, Chevron Texaco; Bonner, Julie, Chevron Texaco; Broderick, Mike, K & M Technology Group (2003). A Multilateral Application in a Limited Hoisting Capacity Environment. *IADC Drilling Conference*. Amsterdam, The Netherlands. 19-21 February.

Buang, N.A,. Zaiton A.M., et al (2006). Effect of Addition of Ni metal Catalyst onto the Co and Fe Supported Catalyst for the Formation of Carbon Nanotubes. *Jurnal of Porous Materials*. 13,331-334.

Cameron, C.(2001). Drilling Fluids Design and Management for Extended Reach Drilling.*MiddleEast Drilling Technology. Bahrain*. 22-24 October.

Collins, P.,(2004).A High Performance Conductive Additivefor Demanding Plastics Applications.

Denny, Dennis. (2008). Extended Reach Drilling Offshore California. *Journal ofPetroleum Technology*. 60(5).

Dojin Kim. (2004).Multi Wall Carbon Nanotubes. Encyclopedia of Nanoscience and Nanotechnology. California USA: American Scientific Publishers. 879-894.

Ezzat, R. and Shabham, S. (2012). Nanosilica with High Surface Area from Rice Husk as a Support for 12- Tungstophoric Acid: An Efficient Nano Catalyst in Some Organic Reactions. *Chinese Journal of Catalysis*. 5 May.

Fann Instrument Company (1996). *Fann Model 212 EP/ Lubricity Tester Instruction Manual*. Houston, Texas.

Fatiha, I., Buang, N.A., et al (2012). Role of Carbon Source in the Synthesis of Carbon Nanotubes via Catalytic Chemical Vapour Decomposition. *Advanced Materials Research*. 364, 16-19.

Georgia, Q., Spiesz, P., Husken, G., and Brouwers, J. (2012). Effects of Amorphous Nano-Silica Additions on Mechanical and Durability Performance of SCC Mixtures. *ICDC International Congress on Durability of Concrete.*

Growcock, F.B, Frederick,T.B., Reece, R.E.,et al (1999).Novel Lubricants forWater based Drilling Fluids. *SPE Symposium*. Houstan, 16-19 October.

Harris, P.J.F. (1999). Carbon Nanotubes and Related Structures. Cambridge.

Hossain, M.E. and Al- Majed, A. A. (2012). *Fundamentals of Sustainable Drilling Engineering.* John Wiley & Scrivener Publisher. Houston, Texas, 630.

IMCO (1979). *Applied Mud Technology Manual*, Catalog by IMCO.

Kercheville, J.D., Hinds.A.A and Clements, W.R. (1986). Comparison of Environmentally Acceptable Materials With Diesel Oil for Drilling Mud Lubricity and Spotting Fluid Formulations.*IADC Drilling Conference*. Dallas, Texas. 10-12February.

Knox, D and Jiang, P. (2005). Drilling Further with Water Based Fluids Selecting the Right Lubricant.*International Symposium Oilfield Chemistry.* Houston, Texas. 2-4 February.

Krishnamororti, R., (2006). Extracting the Benefits of Nanotechnology for the Oil Industry.*Journal of Petroleum Technology*. 58 JPT Online.

Lazaro, A., Brouwers. H.J., Quercia, G. and Geus, J.W.(2012). The properties of Amorphous Nano-Silica Synthesized by the Dissolution of Olivine. *Chemical Engineering Journal*. 211-212.112-121.

Lee, Fred C. (1980). Beaded Liquid Product and Method for Reducing Coefficient of Friction. *Bechtel International Corporation*. San Francisco, Calif, United States.

Lummus, James L., Azar, J.J.,(1986). Drilling Fluids Optimization A Practical Field Approach. Penn Well Publishing Company.

Meghan, R., Steve, Y.,et al. (2012). Wellbore Stability in Unconventional Shale- The Design of a Nano-particle Fluids. *Oil and Gas India Conference and Exhibition. Mumbai, India*. 26-30 March.

Meghan, R., Steve, Y.,et al. (2012).Novel Water base Mud for Shale Gas, Part II: Mud Formulations and Performances.*American Unconventional Resources Conference*. Pittsburgh, Pennsylvania, United State, America. 5-7 June.

M.Meyappan. (2008). Carbon Nanotube Growth by Chemical Vapor Deposition. *Encyclopedia of Nanoscience and Nanotechnology*. California USA: American Scientific Publishers.1-115

Payne, M.L, ARCO British Ltd; D.A. Cocking, BP Exploration; and Hatch, A.J., Anadrill/ Schlumberger (1994). Critical Technologies for Successful in Extended Reach Drilling. *69th Annual Technical Conference and Exhibition*. new Orleon, Los Angeles, United States of America. 25-28 September.

Phuoc, X., Tran, R., et al. (2007). Nanofluids for Use as Ultra Deep Drilling Fluids. *R&D Facts National Energy Technology Laboratory*.

Quiqley, M,C., Mobil R&D Corp (1989). Advanced Technology for Laboratory Measurements of Drilling Fluid Friction Coefficient. *Annual Technical Conference and Exhibition*. San Antonio, Texas. 8-11 October.

Rayborn, Jerry J. (1977). Drilling Fluid Lubricant.2101 Holiday Drive, New Orleans, Los Angeles.

Rabia, H. (1985). *Oilwell Drilling Engineering- Principles and Practice, University of Newcastle, Newcastle*.

Rubiandi, Rudi. (2008). Extended Reach Drilling (ERD) Design in Deepwater Application. *IADC Asia Pacific Drilling Technology Conference and Exhibition*. Jakarta, Indonesia, 25-27 August.

Russel. T., Walder. J., et al (2005). The Use of Carbon Nanotubes to ImproveConductive Elastomers. *Sealing Technology*. November 05

Schamp, J.H. and Estes, B.L., ExxonMobil Development Co., and S.R Keller, ExxonMobil Upstream Research Co. (2006). Torque Reduction Technique in ERD Wells. *IADC Drilling Conference*. Miami, Florida, United State of America. 21-23 February.

Sifferman. T.R.(2003). Starch Lubricant Compositions For Improved Lubricity and Fluid Loss in Water based Drilling Fluids. *SPE International Symposium on Oilfield Chemistry*. Houstan, Texas USA. 5-7 February.

Skalle P., Backe, K.R., Lyomov, Kilaas, S.K., L., Dyrli, A.D., and Sveen, J. (1999). Microbeads as Lubricant in Drilling Muds Using a Modified Lubricity Tester. *Annual Technical Conference and Exhibition*. Houston, Texas. 3-6 October.

Subodh, S. and Ramadan, A. (2010). Vital Role of Nanopolymers in Drilling and Stimulations Fluids Applications. *SPE Annual Technical Conference.* 19-22 September. Florence, Italy.

Sushant, A. (2011). Using Nanoparticles and Nanofluids to Tailor Transport Properties of Drilling Fluids for HTHP Operations. *National Technical Conference and Exhibition. New Orleans, Louisiana*.18-05

Tee, J.C and Goh P.S. (2008). As Grown Multi Walled Carbon Nanotubes (MWCNTs). *Advanced Membrane Technology and Research Centre* (AMTEC), Universiti Teknologi Malaysia.

Zhao, G., Kai,Z., Yi Y, et al (2009). Core/ Shell Nanospheres, Hollow Capsules and Bottles.*Dekker Encyclopedia of Nanoscience and Nanotechnology*. 1865-1879.