Journal of Petroleum Science and Engineering 108 (2013) 64–73

Contents lists available at SciVerse ScienceDirect

Journal of Petroleum Science and Engineering

journal homepage: www.elsevier.com/locate/petrol

Performance analysis of drilling fluid liquid lubricants

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ARTICLE INFO

Article history:
Received 13 August 2012
Accepted 14 June 2013
Available online 27 June 2013

Keywords:
Drilling fluid
Mud
Lubricant
Lubricity
Lubricity coefficient

ABSTRACT

Excessive torque is one of the most important problems in oil/gas drilling industry. Friction between wellbore/casing and drill string causes excessive torque. This study discusses performance analysis of drilling fluid lubricants, which are used as friction reducers in well-bores. Three different types of chemical commercial lubricants, which are fatty acid and glyceride based, triglyceride and vegetable oil based and polypropylene glycol based, diesel oil, and crude oil, which consists of different API gravities, paraffin and asphaltene value samples, are selected for the analysis.

In the analysis section, different lubricant compositions with the mixture of crude oil, diesel oil and lubricants which are added to water based lignosulfonate mud are tested on metal–metal contact surface by the OFITE Lubricity Tester to determine the best lubricity/cost ratio of lubricant compositions.

Moreover, effects of the lubricants on mud rheology and API fluid loss of mud, foam forming potential and cheesing/greasing of the lubricants and the influence of mud properties on lubricants (calcium, salt, pH and mud density) are examined.

1. Introduction

In the process of drilling extended-reach, directional and instable well profiles, the friction caused by dog-legs, key seats, bit balling and hole instability causes excessive torque values. The friction and high torque and drag, which result from drill string and wellbore/casing interaction, causes overpulls in trip-outs, pipe stucks and even lose out the well. Furthermore, inside the casing, energy that is formed from metal–metal surface contact between drill string and casing causes casing wear (Foxenberg et al., 2008).

Oil-based and synthetic-based drilling fluids generally produce lower friction and torque values than the water-based drilling fluids. However, the use of oil-based and synthetic-based drilling fluids is severely limited because of high costs and environmental concerns. As a solution, it is seen that, it would be advantageous to identify a water-based drilling fluid system with addition of lubricants which is environmentally friendly, cost effective and as lubricious as oil-based and synthetic-based drilling fluids (Kercheville et al., 1986).

Lubricants can be divided into two categories: solid lubricants and liquid lubricants. Solid lubricants act like ball bearings that interfere with the contact surfaces without bonding to them. The performance of solid lubricants is independent from the drilling-fluid type as they do not bond. They also may cause plugging problems with BHA components (Schamp et al., 2006). On the other hand, liquid lubricants form a film between the two surfaces that are drill string and casing/wellbore, which is thick enough to mask surface roughness and strong enough to fight with high compressional forces, minimizing the contact area and so friction and torque. As liquid lubricants interact with other surface active additives in the drilling fluid, their performance depends on the concentration of the lubricant (Growcock et al., 1998).

In this study, liquid lubricants are used as friction reducers. Three types of chemical commercial lubricants are triglyceride and vegetable oil based, fatty acid and glyceride based and polypropylene glycol based lubricants. On the other hand, diesel oil, and crude oil, with different API gravities, paraffin and asphaltic value samples are tested. Diesel oil and crude oil are much cheaper than the lubricants and they are easy to obtain in oil/gas fields. However, they are not as lubricious as lubricants. Therefore, it is decided to combine lubricants and crude oil/diesel oil in our water-based drilling fluid and to determine the best composition which has good lubricity performance and low cost.

Water-based lignosulfonate mud is chosen as our base drilling fluid. This type of drilling fluid is the most common and one of the cheapest water-based drilling fluid systems. Moreover, this system is not strong enough to withstand and fight with high torque and its lubricity performance is insufficient. Therefore, the system is considered as our base mud and different lubricants are added to determine the highest lubricant performances. Additives of this

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http://dx.doi.org/10.1016/j.petrol.2013.06.002

base system are treated bentonite, lignosulfonate, CMC, and NaOH. OCMA and barite are also added to this system. Before testing, drilling fluid samples are aged for 16 h in hot rolling conditions at 150 F, in order to ensure the field/down hole conditions and simulate the circulation of the drilling fluid. Also, rheological analysis is conducted at 120 F to simulate the flowline mud temperature. These values are the most frequently met field mud temperatures which are decided to be used in this study to see the temperature effect. High temperature effects are not seen as essential in this paper, as lignosulfonate drilling fluid system is not temperature resistant itself.

OFITE Lubricity Tester (LT) is the equipment that is used to evaluate the lubricity values of the samples. LT gives us the torque value of the samples in lb in. We use calibration constant and calculate the coefficient of friction (COF). COF is used to compare the lubricity performance of the samples.

In order to get the best performance from the lubricants, effects of the lubricants on physical and chemical mud properties are examined. In one study, Tyldsley performed an application of a vegetable oil derivative lubricant called SSP, to overcome the problems of torque and drag in drilling deviated wells. He came up with a result that 30% of reduction in torque values were experienced after adding SSP. He also concluded that SSP helped to stabilize the lignosulfonate drilling fluid systems by lowering the API fluid loss. However, the results showed that SSP raised the yield point value of the mud (Tyldsley, 1979). Therefore, drilling fluid samples are tested on mud rheology that consists of plastic viscosity (PV), yield point (YP) and gel strengths, API fluid loss of mud, foam forming potential and cheesing/greasing potential.

Lubricants are also tested with solid and chemical contaminated and high density drilling fluids. It is known that mud additives like barite and cuttings influence the friction values of the drilling fluid (Skalle et al., 1999). Quigley analyzed the coefficient frictions of various drilling fluid liquid lubricants evaluated in dispersed and non-dispersed mud systems using the mud lubricity tester device. Drilling fluids had a mud density, varying from 67 to 120 ft^3. He concluded that some lubricant additive can reduce bit balling, make better filter cake and stabilize the wellbore, so these effects can decrease the torque and drag. He also noted that low density drilling fluids had a better coefficient of friction (Quigley, 1989). Therefore, the performance of the lubricants is examined at high pH, high calcium ion content, high chloride content and drilling fluid samples with high density.

2. Experimental set-up and procedure

2.1. Sample preparation

Sample preparation in drilling fluids laboratory conditions is essential for the reliability of the tests. In this section, mud additives, mixing and ageing procedures are summarized.

2.1.1. Mud additives

Bentonite, CMC, chrome free lignosulfonate, NaOH, OCMA and barite are mixed to prepare a water-based lignosulfonate base mud. As a lubricant, three types of lubricants, diesel oil and two samples of crude oil with different API gravities are used. Moreover, gypsum and NaCl are used to contaminate the mud to see the lubricant performance in contaminated media. Composition for the base mud can be seen in Table 2.1.

2.1.1.1. Lubricant. Lubricants are used to decrease the risk of pipe stuck and torque and drag values. They form a strong and lubricious film between drill string and formation or casing. In this study, three different types of lubricants are used which are fatty acid and glyceride based, triglyceride and vegetable oil based and polypropylene glycol based lubricants. Also, diesel oil and crude oil, which consist of different API gravities, paraffin and asphaltene values, are used as a lubricant. In Table 2.2, the characteristics of the crude oil samples can be seen.

2.2. Lubricity test

Frictional forces that resist motion come into play, when there is a relative motion between two contacting bodies. In order to decrease the torque caused by high frictional forces in drilling, lubricants are used in water-based drilling fluids. To test the performance of lubricants at laboratory conditions, lubricity test is designed to simulate the speed of the rotation of the drill string and the pressure which the drill string bears against the bore hole wall or casing.

In this study, LT is used to measure the lubricating qualities of the drilling fluids, provide data to evaluate the quantity and type of the lubricating additives and predict the wear rates of the mechanical parts in the fluid systems. One hundred and fifty inch-pounds of torque have been applied to the test block which is running at 60 RPM. After 5 min torque reading is recorded. The tester calculates the mud lubricity coefficient as coefficient of friction (COF) using the torque reading and the correction factor on the equipment. Overview of LT can be seen in Fig. 2.1.

2.3. Mud properties

In order to see the effects of lubricants on mud properties and the influence of mud properties on the lubricant performance, chemical and physical analyses of the drilling fluids are made.

2.3.1. Chemical analysis

In this study, hydrogen ion concentration (pH), chloride and calcium ion concentrations are tested for chemical analysis.

2.3.2. Physical analysis

In this study, density measurement, viscosity and gel strengths, filtration and foam forming potential are tested for physical analysis.

Table 2.1
Composition of the water-based lignosulfonate base mud.

Additives	Amount
Bentonite, lb/bbl	20
CMC, lb/bbl	2
Chrome free lignosulfonate, lb/bbl	3
NaOH, lb/bbl	0.75
OCMA, lb/bbl	30
Barite, lb/bbl	10

Table 2.2
Characteristics of the crude oil samples.

	Crude oil-1	Crude oil-2
API	29.6	19.6
% Water	0.1	0.8
% Deposit	0.4	1
% Paraffin	7.14	7.31
% Asphaltene	3.73	11.97
% Sulfur	1.09	2.91