Rheology steps into a new era of drilling

MODERNIZING API STANDARDS

TAILORING DRILLING FLUID hydraulics is an important key to the success of a drilling operation. Failure to do so can result in costly problems, negatively impact equipment longevity and performance and can ultimately jeopardize overall well objectives.

In recent years, industry methods have deviated from API RP13D Standard Practice. This departure has been driven primarily by the increasingly onerous demands of critical wells, coupled with readily accessible computer power.

The evolution of new hydraulics technologies is creating problems with standardization and uniformity, which in turn is widening the gap between theoretical and practical solutions.

In 2003, a task group was formed to modernize the existing API Recommended Practice Bulletin on Rheology & Hydraulicss. It comprised a cross-functional team of operators, suppliers and academics and set an aggressive target to modernize the existing standard within 2 years. The focus was to develop simple yet accurate methods that could be readily implemented with basic spreadsheet skills.

The resulting bulletin covers rheology fundamentals, downhole fluid behavior, pressure loss determination, hole cleaning, swab-surge, optimization and rigsite monitoring. The target audience is planning engineers together with wellsite implementers.

This paper describes improvements made to the existing procedures and provides an illustration of how these methods can be applied to complex well designs.

The paper also will introduce the industry to a modernized API Standard that offers an ideal foundation to inform the new engineers of the fundamental concepts of hydraulic design and optimization.

Modernization of the API Recommended Practice on Rheology and Hydraulics: Creating Easy Access to Integrated Wellbore Fluids Engineering (IADC/SPE 98743) PA Bern, BP; EK Morton, Chevron; M Zamora, M-I Swaco; R May, Baker Hughes INTEQ; D Moran, Smith International Inc; T Hemphill, Halliburton; L Robinson, Consultant; I Cooper, Schlumberger; S Shah, University of Oklahoma; D Flores, ExxonMobil.

POLYMERIC FLUIDS

Polymers have been widely used as emulsifiers, lubricants, filtration reducers, shale stabilizers, flocculants, viscosifiers and drag reducers in drilling fluids for a number of years. However, due to the complex nature of the various polymers, the actual performance of the polymeric fluids and their properties are not well understood.

A polymer chain molecule may experience elongational flow as it passes through a drill bit nozzle and is accelerated from a low velocity to a higher velocity. If the molecular chains are sheared, the viscosity of the polymeric drilling fluid and the molecular weight of the polymer can be drastically reduced. Therefore, the desired performance of the polymeric fluids in the annulus will not be achieved.

Experiments were conducted on a 190 ft long flow loop (2-in. ID pipe) with PAC, PHPA and XCD at three different concentrations (0.25, 0.375 and 0.5 ppb). Drill bit nozzles (18/32, 20/32 and 22/32-in. diameter) with different sizes were tested in the flow loop with the polymeric fluids.

Three approaches were adopted to determine the effects of elongational flow through drillbit nozzles on polymeric drilling fluids:

1) Rheology measurements;

2) Frictional pressure loss measurements;

3) Molecular weight determinations.

Experimental results show that the rheology of the polymeric fluids was changed significantly upon flowing through the nozzles.

Frictional pressure loss measurements also indicate that the polymeric fluids before and after the nozzles are different.

Results of the molecular weight measurements suggest that the pump does not break the polymer chains. However, the 0.5ppg XCD polymeric fluid collected after the 18/32-in. nozzle presents a significant variation in molecular weight, which indicates that some form of shear degradation of the polymer chains took place.

A coil to stretch transition model (De Gennes, 1974) was applied to determine the critical strain rate in an elongational flow. Experimental results were compared with the model predictions.

This study can help the drilling industry to better understand the performance of polymers after flow through drill bit nozzles.

The Effect of Elongational Flow Through the Drill Bit on the Rheology of Polymeric Drilling Fluids (IADC/SPE 99107) J Lozano, Chevron; SZ Miska, M Yu, NE Takach, University of Tulsa.

DOWNHOLE PRESSURE

Several of the current deepshelf HPHT wells have anticipated bottomhole temperatures that significantly exceed the limits of existing MWD/LWD tools. Therefore, downhole annular pressure measurements are not available for pressure management.

This leaves temperature/hydraulic models as our best, if not only, source of downhole pressure information. However, these models depend on accurate surface inputs and laboratory-measured fluid properties under downhole conditions. Unfortunately these anticipated temperatures and pressures also exceed the operating limits of conventional HPHT viscometers. This lack of measured fluid properties under these extreme conditions will severely limit the ability of hydraulic models to predict downhole pressures.

A new extreme HPHT concentric cylinder viscometer was designed and built to fill this important technology gap for the GOM deep shelf of HPHT wells. The instrument is capable of measuring typical drilling fluid viscosities up to 600 deg F (316 deg C) and 40,000 psig (276.0 MPa) and is capable of obtaining accurate measurements of drilling fluid properties containing magnetic materials.

Subsequent verification and validation testing work proved the new viscometer data compares favorably to commercially available field viscometers and more sophisticated laboratory rheometers and therefore lends itself toward widespread industry use and benefits.

This paper reviews the development of the instrument, automated control system and HSE issues related to testing drilling fluids at these extreme conditions. The paper will also present results of the verification and validation testing on invert-emulsion drilling fluids.

A New Extreme HP/HT Viscometer for New Drilling Fluid Challenges (IADC/SPE 99009) WJ Gusler, ML Pless, JE Maxey, PE Grover, JJ Perez, Baker Hughes; J Moon, TR Boaz, Ametek Chandler Engineering.

RHEOLOGICAL BEHAVIOR

Due to their complex formulations, driling fluids, and especially oil-based muds, exhibit very complex rheological properties. They are commonly described as thixotropic shear thinning fluids with a yield stress.

The American Petroleum Institute offers a set of standards for the rheological characterization of these fluids and classical descriptions with non-Newtonian fluids models. Whereas these descriptions and measurements are adequate for classical drilling situations, they may be insufficient in describing more complex phenomena, such as barite sag or pressure peak due to transient gel breaking on restart. Ultra-low-shear rate rheology, for example, has been accepted as a key parameter for determining sag potential and is poorly described by the classical models and measurements. On the other hand, time-dependent behavior (classically apprehended in static conditions through Gel 0 and Gel 10 measurements), which can be very significant even in dynamic conditions, is not quantitatively linked to the rheological description.

The paper describes how a simple thixotropic and structural model is able to describe completely all the features of the drilling mud's rheological behavior.

The parameters of the model can be simply deduced from onsite measurement using Fann 35 rheometer. We show that muds viscosity results at any moment from the competition between aging and shear rejuvenation. Consequently, viscosity bifurcation (abrupt transition toward complete stoppage or rapid shear) may appear at low shear, which can be related to occurrence of barite sag. Finally, it is shown how any transient phenomena like pressure peaks when starting a pump after circulation stop may be adequately predicted by using this model in hydraulic calculation.

How To Unify Low Shear Rate Rheology and Gel Properties of Drilling Muds: A Transient Rheological and Structural Model for Complex Wells Applications (IADC/SPE 99080) B Herzhaft, A Ragouilliaux, Inst Francais du Petrole; P Coussot, LMSGC.

MICROBUBBLE FLOATATION

The paper addresses the issue of using microbubble floatation technique for cleaning wastewaters such that the output meets or exceeds the US EPA or country-specific standards. Cooperation between academia and the service industry and sharing both field and theoretical studies have revealed:

(1) Microbubbles, using acetylene (C_2H_2) gas medium, at 55 psi back pressure on a dissolved gas flotation pump and constant temperature, can remove 97 percent of the oil and grease from water;

(2) A theoretical scaling law has been proposed for estimating the potential solubility of gas in water, eg CH_4, C_2H_2, where Henry's Law might not be linear due to complex bubble hydrodynamics, pump pulsation, rise of multitude of bubble sizes in fluid column, distribution of number of bubbles, partial pressure and concentration (molality) of the main gas and the leaked air impurities in recycling system;

(3) The mechanism controlling the removal efficiency of floatation cell is related to the number and uniformity of microbubbles rather than their size only; the sizes range from an average of 5 to 200 microns at sampling points;

(4) At sampling points, the bubble count and the gas-filled bubbles as a percent of the unit bulk volume are nonlinear periodic functions of operating pressure of floatation cell; and

(5) There exists an optimal (55 psi) operating pressure of the dissolved gas flotation pump system.

These results show that a mix of gas chemistry and bubble thermo hydrodynamic properties can offer a technique for cleaning wastewater.

Removing Oil and Grease from Waste Water Using Micro Bubble Floatation Technique: From Theory to Field Practice (IADC/SPE 98975) A Hayatdavoudi, University of Louisiana at Lafayette. ■