Section 3. Technical sciences in general

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INVESTIGATION OF PHYSICAL CHEMICAL PROPERTIES OF DRILLING FLUIDS FOR DRILLING OIL AND GAS WELLS

Abstract. The objective of this work is investigation of physical and chemical properties and development new receipt of weighted drilling fluids for drilling oil and gas wells. In the article the main physical and chemical properties of the weighted drilling fluids for drilling oil and gas wells have been given. The methods of testing drilling fluids and materials used for obtaining weighted drilling fluids have been investigated.

Keywords: drilling fluid, properties, test, standards, weighting, receipt, well, oil and gas.

Introduction

The properties of drilling fluids play important role for oil and gas well drilling. Drilling fluid density is usually called mud weight. Normal pressure formations generally have a pressure gradient similar to a water gradient. For various reasons formation fluid pressures are frequently higher. Barite or hematite is used to increase the drilling fluid density. This increases the hydrostatic gradient in the well bore so that the pressure in the well bore is higher than formation pressure [1; 2].

The most essential properties of drilling fluids are viscosity, mud weight or density, filter cake, Solid's content, gel strength toxicity, fluid rheology, fluid loss, particle plugging, high-angle sag and dynamic high-angle sag, high-temperature fluid aging, cuttings erosion, shale stability, capillary suction time (CST), return permeability, X-ray diffraction and particle-size distribution (PSD).

Materials and methods

As a material for obtaining drilling fluids used water, bentonite, carboxymethyl cellulose, gossypol resin, barite ($BaSO_4$) and NaOH, Na_2CO_3. Investigations of drilling fluids properties carried out according API (API RP 13-B_1, B_2) standards. The viscosity is defined as the resistance of fluid to flow. The concepts of viscosity, shear stress, and shear rate are important in understanding the flow characteristics of fluids. Specific measurements are made on fluids to determine rheological parameters under a variety of conditions. Determination of viscosity using the Marsh funnel.

Determination of viscosity and/or gel strength using a direct-indicating viscometer.

The viscosity of drilling fluid is a function of:
- Viscosity of the continuous phase or the base liquid;
- The size, shape and solids particles in the mud which is represent it by the plastic viscosity;
- The inter-particle force represents it by the yield point.

The plastic viscosity is the resistance to flow caused by the friction between solid particles. The yield point is the resistance to the initial flow or the stress required to start flowing. The yield point is measured under flowing conditions.

Reducing viscosity in any drilling fluid can be achieved by:
- Reduction of solids by mechanical treatment or dilution;
- Neutralization of attractive forces between particles [3; 4].

Mud weight or density

The density is the weight per unit of volume. During operations mud weight has to be well controlled and need adjustment. If the mud weight is less than the required level of density to drilling safely can permit the formation fluids to flow into the well and lead to well control situation and if it is higher than the appropriate level it can lead to lost circulation situations. Mud weight were tested by 4-scale Metal Mud balance. The real mud weight under circulation is greater than the density while drilling fluid is in static. This density is called equivalent circulating density (ECD). When designing hydraulics, the ECD has to be less than fracture gradient [5].

Filter cake

The filter cake is formed when mud solids deposit on the walls of the hole. The filtration is the loss of fluids from mud into the formation. The main objective of controlling fluid loss is forming thin filter cakes while drilling through permeable formations and preventing excessive fluid loss (filtrate).

Loss of drilling fluids in formation can lead to high water consumption and thick filter cake which can cause a tight hole, increased torque and consequently lead to stuck pipe.

Solids content

Solids can be:
- Added to the drilling fluid in order to increase viscosity or weight;
- Accumulated in the fluid like drilled cuttings or disintegrated clay particles.

The treatment of solids has to be effective to remove undesired solids which do not contribute to beneficial properties.

Gel strength

Gel strength represents the attractive forces under static conditions (non-flow conditions). Contrary to gel strength, the yield point represents the attractive forces under flowing conditions. The gel strength gives an indication of the required pressure to initiate flow after ceasing circulation for period of time. Also, it gives an indication about the ability of the drilling fluid to suspend cuttings when mud is stationary.

Gels are classified into two types:
- Progressive that starts low but increase with time;
- Fragile that starts high and increase slightly with time.

Toxicity

The environmental and toxicity standards of the region in which the fluid is being used will require testing either of the whole drilling fluid or of its individual components. Toxicity tests generally are used for offshore applications. An approved laboratory can perform the proper testing to ensure compliance of the fluid or its components.

Fluid rheology

Fluid rheology is an important parameter of drilling-fluid performance. For critical offshore applications with extreme temperature and pressure requirements, the viscosity profile of the fluid often is measured with a controlled-temperature and -pressure viscometer (e.g., the Fann iX77 Rheometer). Fluids can be tested at temperatures of < 35 °F to 500 °F, with pressures of up to 20.000 psia.

Cold-fluid rheology is important because of the low temperatures that the fluid is exposed to in deepwater risers. High temperatures can be encountered in deep wells or in geothermally heated wells. The fluid can be under tremendous pressure downhole, and its viscosity profile can change accordingly.

Fluid loss

If fluid (or filtration) loss is excessive, the following can occur:

- Formation instability;
- Formation damage;
- Fractured formation and loss of drilling fluid.

In the field, LP/LT(Low Pressure/Low Temperature) and HP/HT(High Pressure/High Temperature) fluid-loss tests are performed routinely. Fluid loss also can be measured under dynamic conditions using the Fann Model 90 Dynamic Filtration System, which incorporates a rotating bob to provide fluid shear in the center of a ceramic-filter core. The fluid is heated and pressurized. Fluid loss is measured radially through the entire core, giving a sophisticated simulation of the drilling fluid circulating in the wellbore.

Particle plugging

The particle-plugging test (PPT) often is used to evaluate the ability of plugging particles added to a fluid to mitigate formation damage by stopping or slowing filtrate invasion into a core. A PPT uses an inverted HP/HT-filter-press cell that has been fitted with a ceramic disk as a filtering medium and is pressurized with a hydraulic cylinder. Ceramic disks with different mean pore-throat diameters are used to simulate a wellbore wall. A PPT typically is run with a 2.000-psi or higher differential pressure. The spurt loss and total fluid loss are measured over a 30-minute period. The cell is inverted, and fluid loss is measured from the top of the cell to eliminate the effects of fluid settling.

High-temperature fluid aging

Over time, high temperatures can degrade the components of a drilling fluid, and alter its performance. High-temperature aging of the fluid is conducted to assess the impact that temperatures > 250 °F have on performance. Fluid can be aged statically and dynamically. In the static-aging process, the fluid is placed in a pressurized cell, and allowed to stand without rolling at the desired test temperature for a desired length of time (rarely < 16 hours). This simulates the stress the fluid might be subjected to during static periods in the wellbore (e.g., logging and tripping). In dynamic aging, the fluid is rolled in a pressurized cell at the desired test temperature to simulate the fluid under drilling conditions. After undergoing aging, the fluid can be evaluated using the same tests that are applied to non-aged fluid.

Shale stability

Reactive shales cause many difficulties in a drilling operation. Fluids should be designed to mitigate these shale problems. Along with erosion testing, four other distinct tests are used to assess the interaction between the drilling fluid and shale: capillary suction time (CST), return permeability, X-ray diffraction and particle-size distribution (PSD).

CST

The CST test investigates the chemical effects of the drilling fluid on the dispersive properties of shale and active clays. The CST test measures filter-cake permeability by timing the capillary action of filtrate onto a paper medium. Changes in permeability then can be related to the inhibitive characteristics of the fluid [4].

Return permeability

When drilling reaches a hydrocarbon-bearing zone, of great concern is the potential to damage the formation and thereby to reduce the ability of the well to produce hydrocarbons. A return-permeability test can reveal formation damage, and can be conducted using a return permeameter.

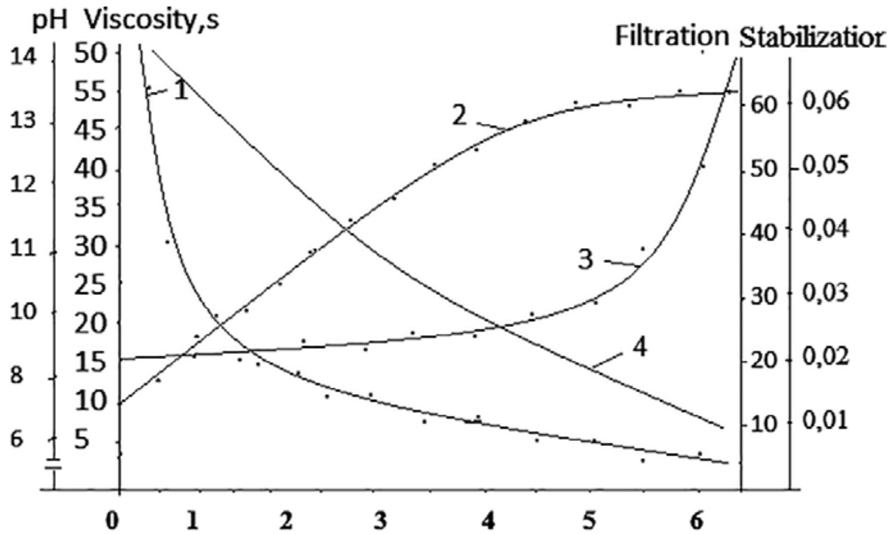
X-ray diffraction

Knowing the mineral composition of a formation to be drilled is important for determining how the drilling fluid will react with the formation, and how to prevent potential drilling problems. Fluid labs use X-ray diffraction to determine the mineralogical composition of shale or cuttings. They expose a crystalline mineral sample to X-ray radiation, and compare the resultant diffraction pattern to known standards to determine which minerals are present in the sample.

Result and discussions

Not only our investigations but also the American Petroleum Institute (API) publishes documents relating to oilfield standards, including drilling fluids testing procedures. As with any laboratory procedure requiring the use of potentially hazardous chemicals and equipment, the user is expected to have received proper training and knowledge in the use and disposal of these potentially hazardous materials. The user is responsible for compliance with all applicable local, regional, and national requirements for worker and local health, safety, and environmental liability.

Ivestigations of physical chemical properties of drilling fluids are given on Figire 1.



Concentration of reagent MBR,%

Figure 1. Dependence of water filtration (1), pH(2), Viscosity (3) and stabilization index (4) from concentration of CCR

The results of шnvestigations show that on basis of the chemical reagent MBR, CMC and barite we can receive weighted drilling fluid with a density of 1.55–2.40 g/cm^3. The pH of the heavy mud on basis of the composite chemical reagent reaches 9–10 or without the addition of caustic soda. Concentration barite is 40–60%. The composite chemical reagent also has a positive effect on the flow properties as well as filtering solution decreased from 12 to 5 cm^3/30 min. Stabilization drilling fluid is one of the main physic-chemical property of drilling mud. Stability drilling fluid is ability of solution to hold particle weighted distribution. It determinates quantity difference of density bottom and top half of the drilling fluid sediment in 24 hours.

Table 1. – Typical Field Tests For WBF

Drilling-fluid density	Mud weight, in ppg or equivalent unit of measure, as appropriate to the region [e.g., specific gravity (SG)].
Viscosity	Viscosity exhibited when a specific quantity of fluid is poured through a Marsh funnel (typically recorded in seconds per quart).
Rheology	Rheological properties exhibited at various rotational speeds using a viscometer (also called rheometer). The Fann* 35 viscometer can test the fluid at multiple speeds and temperatures to give a detailed viscosity profile for the fluid.
Gel strength	Suspension characteristics developed over specified time intervals.

Filtration	Surface indication of filtrate invasion into the near wellbore (also called fluid loss). Performed under LP/LT conditions and HP/HT conditions as required.
Retort analysis	Percentages of water, oil, and solids making up the active system.
Sand content	Percentage of sand in the active system.
Methylene blue capacity	Clay content in the active system [also commonly called methylene blue test (MBT)].
pH	Indication of system acidity or alkalinity.
Chemical analysis: Alkalinity/lime content Chlorides Total hardness (calcium)	Indication of variations from base-fluid formulation caused by surface treatment and/or influx or contamination from downhole formations.

** Fann is the registered name for fluids-testing equipment provided by Fann Instrument Co., Houston*

Extensive testing of the fluid is performed in the design phase of the fluid, either to achieve desired fluid characteristics or to determine the performance limitations of the fluid.

Laboratory testing aids in fluid design and expands the capacity to monitor and evaluate fluids when field-testing procedures prove inadequate. Some laboratory tests are identical to field-testing methods, whereas others are unique to the laboratory environment. In the laboratory setting, testing and equipment should determine following properties for drilling oil and gas wells:

– Toxicity;
– Fluid rheology;
– Fluid loss;
– Particle plugging;
– High-angle sag;
– Dynamic high-angle sag;
– High-temperature fluid aging;
– Cuttings erosion;
– Shale stability;
– Capillary suction;
– Lubricity;
– Return permeability;
– X-ray diffraction;
– Particle-size distribution (PSD).

Investigations show the successful oil well drilling depends largely on a good mud Program. During drilling, mud provides sufficient hydrostatic pressure, removes drill cuttings and cools drill bits. Mud additives are always required to provide sufficient hydrostatic pressure to ensure borehole stability. Barium Sulphate ($BaSO_4$) also known as barite is the prevalent weighting material but there is need to develop local materials to augment the use of Barite. This study was aimed at assessing the suitability of galena, a lead sulfide (PbS), as an alternative weighting material in drilling fluids.

Conclusions

Based on the above results, we can conclude that the density, stability, viscosity and filtration of drilling fluids play main role to drill oil and gas wells without accident. Investigations show that safety drilling oil and gas wells depend on geological conditions and the optimum apparent viscosity value is approximately 40–60 s, for filtration value is 3–8 sm^3/30 min, for density value according to the layer pressure and for pH value is 9–10 for water based drilling fluids.

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