الجمهورية الجزائرية الديمقراطية الشعبية

People's Democratic Republic of Algeria

Ministry of Higher Education
and Scientific Research
Higher School of Applied Sciences of Algiers

وزارة التعليم العالي والبحث العلمي
المدرسة العليا في العلوم التطبيقية بالجزائر

Department of the second cycle

A Dissertation

In view of obtaining the **Master's degree**

Field : Process Engineering

Specialty : Organic Processes

Theme :

State of the art on drilling muds

Presented by : BAYOU Manel

Supervised by : BERKACHE Kamel

Co-Supervised by : DEGHMOUM Mohamed

Defended on: 22/06/2023

In front of the jury composed of:

Ms. SMAIL Fatima	MAA	ESSA-ALger	President
Mr. BOUTRA Abdelkader	MCA	ESSA-ALger	Examiner
Mr. BERKACHE Kamel	MCA	ESSA-ALger	Superviser
Mr. DEGHMOUM Mohamed	MCB	SONATRACH	Co-Superviser

Binomial N° : 15PO/MASTER/2023

Abstract

Drilling fluids have complex and often variable behavior depending on their formulations and the conditions in which they are used. We aim to characterize and quantify the effects of particle interactions on the microscopic properties of drilling mud, which is the focus of this topic titled "The state of the art of drilling mud." Controlling and mastering these properties allows us to predict their behavior at all stages of drilling and recommend different formulations for tasks such as hole cleaning and debris removal. The rheological behavior laws of drilling mud are difficult to define theoretically, and currently, experience remains the only path to mastering them.

Résumé

Les fluides de forage ont un comportement complexe et souvent variable suivant leurs formulations et les conditions dans lesquelles ils sont utilisés. On se propose de caractériser et de quantifier les effets des interactions entre les particules sur les propriétés à l'échelle microscopique des boues de forage qui est l'intérêt de ce sujet intitulé « L'état de l'art des boues de forage ». Leur contrôle et leur maîtrise permettent de prévoir leur comportement à toutes les phases du forage et de recommander différentes formulations (nettoyage du trou, remontée des déblais….). Les lois de comportement rhéologique des boues sont difficiles à définir sur le plan théorique, et que l'expérience reste actuellement la seule voie permettant de les maitriser.

ملخص

السوائل الحفرية تتصف بسلوك معقد ومتغير في كثير من الأحيان تبعًا لتكويناتها والظروف التي يتم استخدامها فيها. نهدف إلى توصيف وقياس تأثير التفاعلات بين الجسيمات على الخواص المجهرية للطمي الحفر، وهذا هو محور هذا الموضوع المعنون "الحالة الفنية للطمي الحفر". يتيح السيطرة والاستيلاء على هذه الخواص لنا توقع سلوكها في جميع مراحل الحفر وتوصية بتراكيب مختلفة لمهام مثل تنظيف الثقب وإزالة الحطام. قوانين السلوك الريولوجي للطمي الحفر تعتبر صعبة في التعريف نظريًا، وحاليًا، يظل التجربة هي السبيل الوحيد لاستيعابها.

Acknowledgments

I would like to express my sincere gratitude and appreciation to all those who have contributed to the successful completion of this project.

First and foremost, I am deeply thankful to our superviser, Mr BERKACHE Kamel for his invaluable guidance, support, and mentorship throughout the entire duration of this project. Their expertise and insights have been instrumental in shaping the direction and quality of our work.

I immensely grateful to our co-supervisor, Mr DEGHMOUM Mohamed for agreeing to co-supervise our work, as well as for their availability, valuable guidance, their constant encouragement and insightful discussions.

I would also like to extend my heartfelt appreciation to the president of Jury and examiner, Mrs SMAIL Fatima and Mr BOUTRA Abdelkader, for their valuable feedback and constructive criticism, which have greatly enhanced the overall quality of this project as well as the time they dedicated to studying this work.

BAYOU Manel

Contents

List of figures

General Introduction

The composition of a drilling fluid directly depends on the type of mud. Fluids drilling can be water-based or oil-based primarily. Currently based fluids of oil are used in technically difficult cases such as wells with high temperatures, deviated wells or drilling of clay zones. However, these fluids have limitations relating to the protection of the environment. Water-based fluids are increasingly used and known to be a non-polluting alternative to sludge to the oil. However, they lack the essential properties for effective use in high temperature areas and in swelling clay formations.

Water-based drilling fluids generally have a complex composition, they contain clay, various dispersant additives, viscosifiers, weights and electrolytes. Each product has a well-defined role in drilling muds so that all the elements interact to give the mud specific properties facilitating its passage through porous formations, without losing its properties of well clogging and stability. The choice of the type of mud, the products and the additives which will give the mud the properties required (density, viscosity, gel strength, filtration) are always matters of interest, and this with the aim of improving the functions of the mud during the drilling operation. Drilling muds can be prepared in such a way that their physical properties respond to a set of rational conditions, and solve problems encountered during drilling such as abnormal pressures, loss of mud, loose clays etc. Choosing the right mud additive is tricky because of what each additive influences comprehensively on all basic parameters at the same time.

Chapter 1

Generalities of drilling muds

1.1 Introduction

Drilling fluids are the backbone of all modern drilling operations, although they represent only less than 8% of total expenditure. Drilling fluids technology is dominated by three main factors: performance, profitability, and environmental and safety concerns. It's clear that the primary purpose of the drilling fluid is to achieve the best performance that will enable all of the construction and operating operations of the well. However, it must be available, cost-effective, and not harmful, either to health or user safety and the environment.

1.2 Drilling muds definition

The drilling fluid, also called drilling mud, is a system composed of different liquid constituents (water, oil) and/or gaseous constituents (air or natural gas) containing in suspension other mineral and organic additives (clays, polymers, surfactants, cuttings, cements, g). The drilling fluid was already presented in 1933 at the first World Congress of Petroleum, where it was the subject of five communications [1]. The first treatise on drilling fluids was published in 1936 by Evans and Red.In 1979, the American Petroleum Institute (API) defines drilling fluid as circulating fluid continues throughout the duration of the drilling, both in the borehole and on the surface. The fluid is prepared in sludge tanks, it is injected inside the rods up to the tool from where it rises in the ring finger, loaded with cuttings formed at the working face (Figure 1-1).

On leaving the well, it undergoes various treatments, sieving, dilution, addition of products, so as to eliminate the transported cuttings and to readjust its physicochemical characteristics to their initial values. It is then reused (Landriot, 1968) [2].

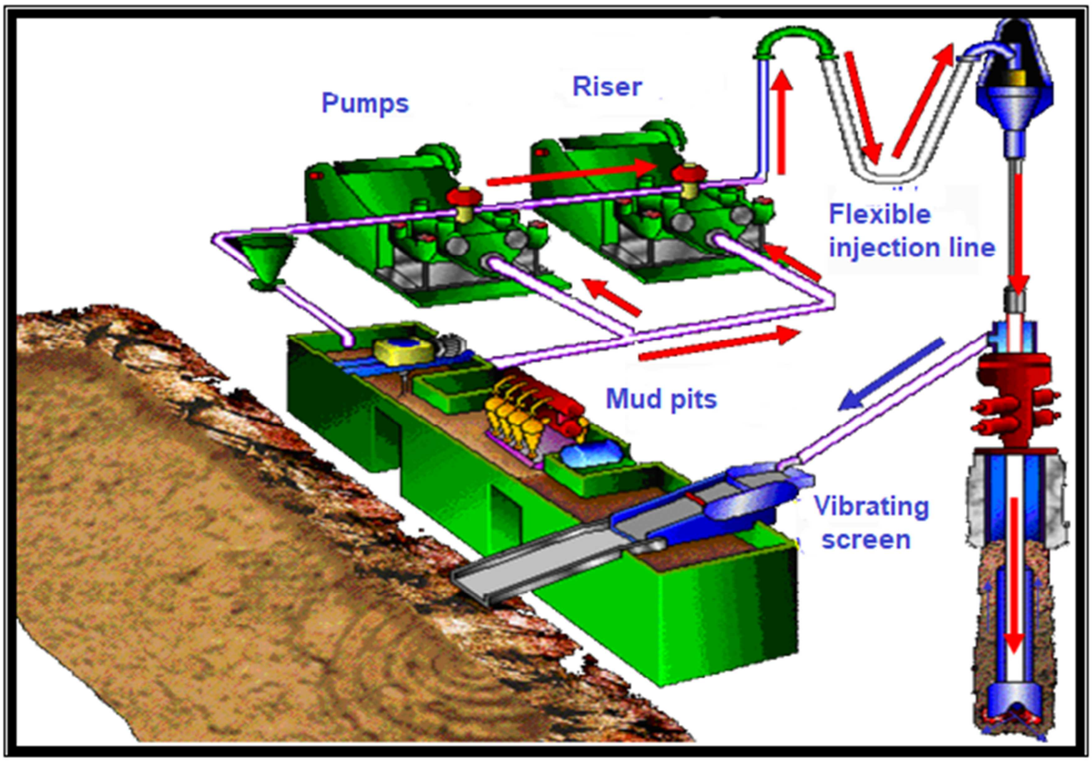

Figure 1-1- Diagram of mud circulation on the drilling site

1.3 State of the art on drilling muds

In 1983, Poley and Wilkinson did a study on the effect of cuttings from offshore drilling in the waters of the North Sea, on the surrounding environment. The authors divide the extent of the impact in three zones, with an increasing degree of contamination in the direction of the unloading site and low and progressive biodegradability in the direction reverse.

In 1984, Bannett offered a paraffinic mineral oil as a base fluid for oil-based muds. The author gives the composition of the new mud, and results certified, demonstrate its effectiveness and a much lower efficiency than that based on Diesel.

As part of research to improve water-based muds:

Clark and Co already published in 1976, a discussion on Potassium-based muds / polymer used effectively for drilling muds of sensitive clay formations. The authors give the formulation used (Potassium Chloride system / polymer with partially hydrolyzed high molecular weight polyacrylamide) as well as results from laboratory and field has demonstrated its effectiveness in stabilizing clays.

In 1980, Chesser and Enrigh proposed the sodium salt of the low-weight distributer molecular Styrene sulfone-maleic anhydride of ABAB sequence and weight molecular weight 1000 to 5000 as a deflocculant and stabilizer of the rheological properties of water-based muds at high temperatures high pressures.

In 1981, Wiliams Jr. and Underdown give the amino cationic polymers, in especially polyamines and quaternary polyamines, as excellent stabilizers clays. This power is further improved with the quaternary polyamine / strong acid.

In 1991, Retz et al demonstrated the mechanism of inhibition of clays by a certain number of cationic polymers, with less aptitude, and better compatibility with other sludge constituents. A comparative study with other types of sludge has been to come true.

In 1992, Plank listed a series of synthetic polymers used as additives deflocculants, thinners, filtrate control, and shear thinner, for water-based muds, during high temperature forage.

In the same year, Beihoffer and co facilitated the performance achieved for the inhibition of clays with a formulation containing 10% KCl / 0.4% favored cationic dimethylamine – epichlorohydrin.

Also, Hemphil et al. relate mud performance to cationic polymers Used in forage of highly permeable sandy areas and formulations highly dispersible clays. The results show great efficacy in concerns: the stabilization of clays, the anti-jamming of the tool, the filtrate, the cake, the speed of penetration and resistance to solid contaminants.

Also in 1992, Zakharov and Konovalov offered low-cost and low toxicity as inhibitors and thinners. These products are based on silicone, phosphorus, Aluminum, and boron, combined with other water-based sludge additives.

In 1994, Stricland emphasizes the importance of sludge to polymers, and compares their characteristics and performance, with that of oil-based muds. The comparison deals with thermal stability, stabilization of formulations, protection of the area productive, lubricating, environmental protection, corrosivity, and resistance to contaminants.

The same year Zakharov and co propose particular additives like reducers of filtrate, gelling agent, pH regulator, lubricant, thinners and inhibitors. These additives are made from a combination of chemicals with industrial waste with no effect harmful to the environment.

In 1995, Stamatakis and co proposed new clay inhibitors. These additives are economical, non-toxic and thermally stable. They are rated OCMs (organic cationic materials).

In 1996, Ding Rui and co propose additives to silicates for the stabilization of clays. These water-soluble additives act on clays by blocking cracks of surfaces, either by inhibition of hydration or by reaction.

The same year, Fausto and co, 1996 propose a Zirconium bass additive for the control and stabilization of the rheological properties of bentonite sludge at high temperatures. This product, less expensive and less toxic than conventional products based on of chromium, seems to give the same results.

Also in 1996, Hemphil and Larsen published a comparative study between sludge with oil-based and improved water-based sludges

In 1997, Van Oort and co describe the effect of polyglycol-polymer interactions on the stability of the latter at high temperatures high pressures in muds based on of water. They report the interaction mechanisms and influential parameters for four types of these polyglycols.

Also, in 1997, Elward Berry and Darby proposed a new water-based system, not toxic and stable at high temperatures, thanks to a particular fluid; Water Based High Temperature Fluid noted (WBHT). The system is designed to maintain the stability of the rheological properties up to 400 – 475 F° without the use of deflocculants.

In 1998, Seaton and co reported the performance of an improved water-based mud to the glycol. The latter forms a microemulsion in the aqueous phase giving a high effectiveness to the formulated mud.

In 1999, Argillier and co carried out extensive laboratory research on the behavior of three types of recent use sludge. This is a Mixed formulation Metal Hydroxide (MMH), and two formulations for high temperatures and high pressures. The investigations were spread over static and dynamic filtration with a simulation of the invasion of this type of sludge and the damage caused to the area producer.

In 2001, Vassilivich reported the performance of polymer muds with respect to the increase in the speed of penetration, the reduction in the damage to the formations, the prevention of hole enlargements, and the properties of filtration and cake. Regarding systems based on synthetic fluids:

In 1993, Friedhein and Pantermuehl reported the results of the use for the first time with a fluid based on polyalphaolefins. The fluid showed good performance, and properties of biodegradation, bioaccumulation, compatibility with the material, and thermal stability, better than those based on ester or ether.

Again, in 1993, Candler and co published a comparative study between the three main types of sludge. These are muds based on synthetic ester, ether and polyalpholefins on the one hand, that based on oil (diesel and mineral) and certain sludges based on water on the other hand. The same year Kenny reported on the use of an ester-based mud in a long-range drilling in a very sensitive clay formation.

In 1994, Growcocke et al studied the physico-chemical properties of muds based on synthetic fluids in relation to their impact on the environment, thermal stability, rheology, clay dehydration and material compatibility.

In 1996, Viel et al published an article on synthetic fluid-based muds emphasizing their great interest in safeguarding the environment.

In the same year, Kenny and Hemphill describe the excellent carrying and cleaning the hole with an ester-based mud, used in the 12 1/4 in and 8 1/2 in sections. They also modeled the rheological behavior of the mud used.

Also, in 1996, Friedhiem and Conn studied the properties of the second generation of synthetic fluids for drilling muds, used from the second half of the 90s. They also give a description of the chemistry of these products and an overview of the aspects: economic, technical and environmental in comparison with the first generation.

Also in 1996, Growcock and Fredick discuss the high temperature limits of muds based on synthetic fluids. These limits are the most sensitive for the stability of emulsion (water-synthetic fluids) and rheological properties. The authors offer to improve these characteristics by increasing the concentration of surfactants and rheological stability agents.

In its sixth issue of 1999, World Oil reports a classification of different types of drilling fluids, plus definition, function, name commercial, and the suppliers of each product. The terminology used is consistent with that adopted by the American Institute of Petroleum API and by the International Association of Drilling Contractors (IADC).

In the edition of the same magazine in December 2007, she published a report on solids control devices that must be able to handle the different characteristics of solids. When drilling fluids are used, recovering as much of the fluid as possible is a heightened concern [3].

1.4 Role of drilling mud

Drilling muds must have properties allowing them to optimize the functions following:

- Ensure the raising of the cuttings from the bottom of the well to the surface by circulation of a viscous fluid in the annular space (well cleaning).

- Keep the excavated material in suspension during a traffic stop in order to prevent the sedimentation of cuttings in order to restart drilling without jamming thanks to the rheological nature of the fluid.

- Cool and lubricate the tool to prevent rapid wear of metal parts in movement.

- Maintain the walls of the well due to the hydrostatic pressure exerted by the fluid in flow and make it possible to control the influx of fluids from the rock formations crossings. Because of this pressure difference, the fluid will "filter" into the permeable formations and deposit a film on the wall called "filtration cake".

- Increase the penetration speed of the tool.

- Ensure the prevention of water, gas or oil leaks.

- Provide survey information [4].

1.5 Types of drilling mud

During drilling, the required properties of the drilling fluid change accordingly change in downhole conditions. The efficiency of the drilling operation depends therefore closely from the adaptation of the properties of the fluid to the different Requirements emanating from the hole. For this, there are different types of drilling fluids including the properties can be close or very different.

According to the base constituent there are four types of drilling muds: water-based muds, oil-based, synthetic-based, and pneumatic fluids [5]. These base fluids can also be present in the same mud.

In general, the different constituents belong to one of the three phases that can constitute the sludge:

- The continuous phase which is the basic fluid in which are dissolved, in suspension and/or emulsion, the other constituents.

- The solid phase made up of the various solid particles contained in the mud.

- The discontinuous phase of the emulsified fluid in the continuous phase.

1.5.1 Water based muds

The vast majority of drilling operations use water-based muds. These have the following general composition:

- Water occupying most of the volume and possibly containing oil emulsified and soluble chemicals;

- Clays, added or coming from drilled formations, colloids organic, and supersaturated products;

- Inert solids which act only by mass effect and are insensitive to chemical action, such as sand, limestone, dolomite, and barite.

These fluids are often referred to as "Water-Based Muds" or WBM. They are in the most cases consisting of suspensions of bentonite in water (30 to 60 g/L) whose rheological and filtration characteristics are often adjusted by polymers. The nature of the electrolytes and their concentration in the formulations of water-based muds are chosen taking into account the characteristics of the formation (water activity of clay formations, dissolution of saline formations).

Among the additives we can find:

- Viscosifiers : natural clays (often bentonites), polymers synthetic or biopolymers;
- Filtrate reducers used to consolidate the filter cake to limit the invasion by the fluid: starches, carboxymethylcelluloses or CMC, polyanionic celluloses (PAC), or resins;
- Clay swelling and dispersion inhibitors: KCl, glycerol, silicates or various polymers such as polyacrylamide partially hydrolyzed (PHPA), polyalkylene glycols (PAG);
- Weighting agents such as barite (“barite” or barium sulphate) $BaSO_4$) and calcite (calcium carbonate $CaCO_3$) which are the most used to ensure the mud has a suitable density. We also note the use hematite (Fe_2O_3) or galena (PbS). Calcite is often recommended for reservoir phase drilling because of its solubility in acid and its use according to a variable particle size for reduce problems of loss and damage; and finally
- Sealants, rather exotic additives such as granular (shells nuts), fibrous (wood fibers, sugar cane), and lamellar (oyster shells, cereals) [6]

Depending on the need and availability, the water can be fresh, salt or downright sea water.

1.5.2 Oil based muds

The origin of the use of oil in drilling fluids goes back to the first drillings carried out in Oklahoma City (1934-1937) during which a improved drilling performance after adding crude oil (Lummus et al., 1953).

Oil-based fluids are fluids whose continuous phase is mineral oil (crude oil, fuel, diesel, etc.) and the dispersed phase is water. By definition fluids oil-based drilling muds containing more than 5% water are called drilling muds in reverse emulsion; with less than 5% water, we have oil-based sludge [7] .These fluids are often referred to as "Oil-Based Muds" or OBM. The most used continuous phase until recent years was diesel, but currently the legislation relating to the environmental protection requires the use of mineral or "synthetic" oils, no longer containing aromatic compounds. Emulsifying and wetting agents are then used to promote the stability of the emulsion.

The rheological properties (thixotropy) of this emulsion are adjusted by the addition of viscosifying agents, generally organophilic clays. Formulations may also contain filtrate reducing agents (asphaltenic compounds and polymers) and other special additives. It should be noted that today most research work focuses on the improvement of synthetic reverse mud, given their economic and environmental advantages, compared to fluids diesel-based conventional walls of the well (no cake) [8].

Safety concerns about the use of in-tank foam are to report, in particular explosions in the event that the volume of gaseous hydrocarbons is between 3 and 10% with respect to air. This is the case in 1992, of the RB-13 well in Algeria, where during a well recovery operation ("work-over") with mud at the foam to prevent loss of circulation, an explosion occurred following a contamination of the mud by an influx of oil or gas (Abid, 1995) [8].

1.6 Formulation

1.6.1 Gels

The drilling fluids are preferably shear-thinning threshold fluids. How give this characteristic to a water-based liquid?

One (inexpensive) solution is to add very fine particles such as clay; certain clay particles tend to agglomerate in water forming a three-dimensional network: a gel is thus obtained. The advantage of these materials is that the interaction forces that bind these particles are fragile: a slight agitation is enough to break the network, thus making the suspension more fluid. A shear-thinning fluid is effectively obtained with a yield point.

1.6.2 Influence of cuttings

The advantage of clay particles is that they are often generated by the drilling itself, so they cost nothing. However, drilling in clay soil can also generate too high a clay concentration, and therefore a yield point and a viscosity incompatible with pumping. To avoid this, the concentration of solids can be reduced fines in the drilling fluid using solids handling equipment (centrifuges and hydro - cyclones). The concentration of fine solids is then regularly measure to avoid drift.

1.6.3 Composition of the different types

Historically, drilling fluids evolved from a simple mixture of water and clay called "mud" to more and more complex systems composed of water or oil with a multitude of additives meeting the required characteristics and problems encountered. Drilling fluids are complex fluids classified according to the nature of their basic constituents. Traditionally, drilling fluids have been classified into three categories according to the basic fluid used in their preparation: air, water or oil) [9]. The properties required of drilling muds are multiple and can sometimes even be contradictory. The sludge must, for example, be very viscous to ensure the rising of the cuttings, but the viscosity must not be too high in order to limit pressure drops due to flow and to avoid formation fracturing. Many components

Multifunctions are therefore added to the mud to give it the desired properties. He is possible to roughly classify these components into 20 categories (Table 1-1**Erreur ! Source du renvoi introuvable.**).

Table 1-1 : Main additives used in drilling fluids [10]

1	Controller of alkalinity	11	Lubricants
2	Bactericides	12	Release agents (or penetratingagents)
3	Anti-calcium	13	Inhibitors of swelling of the clays
4	Inhibitors of corrosion	14	Products facilitating separation
5	Defoamers	15	High temperature stabilizer
6	Foaming agents	16	Deflocculants
7	Emulsifiers	17	Viscosifiers
8	Filtrate reducers	18	Weighting
9	Flocculants	19	Brine
10	sealants	20	Mineral or organic oil

Chapter 02

Composition of drilling fluids

2.1 Drilling fluid components

Due to their low toxicity rates, water-based muds are preferred over other systems, but some cases require other oil-based formulations for successful drilling execution. On the other hand, in wells drilled with oil-based muds, their reuse is easy, these muds are only cleared of the evacuated cuttings. The average loss volume of oil-based muds (volume of mud that adheres to the drill cuttings) is estimated at 2,000 to 8,000 barrels per well [11]. Oil-based muds contain diesel or conventional mineral oil as the continuous phase. These muds are inexpensive and were the only ones in service until the end of the 1980s [12].

2.1.1 The aqueous phase

Water-based muds are increasingly used, given their low toxicity rates, the added elements such as starch and biopolymer are biodegradable, as for the biocide and the pH corrector, their dosage is too low to constitute any danger for the layers crossed. The formed freshwater-based mud is developed for areas of high permeability and high temperatures of 50 to 180°C, intended for the crossing of reservoir rock.

2.1.2 THE SOLID PHASE

The solid phase consists of the weighting agent, potassium chloride, starch, clays, biocide, potassium hydroxide and biopolymers. Most of these products come in the form of a powder, the biocide in the form of a tablet and the potassium hydroxide in the form of crystals. These components are essential to the drilling mud, they have been carefully selected so that each element correctly fulfills its role while acting in synergy with the system used.

2.1.3 Weighing down

The density is the ratio of the density of a reference body under the conditions which must be specified for the two bodies (water at 4°C for liquids and solids, air for gases). A density must be sufficient to counterbalance the pressure present at the bottom of the well and avoid the fracturing of the rock, indeed it contributes to avoid the eruption of the fluids contained in the formations, it participates in the good behavior of the hole; but it can also be responsible for a loss of circulation; and its increase may tend to increase the pressure drops (in the parts of the circuit where the flow is turbulent) as well as the losses by filtration. The weighting agent should have a higher density to achieve a high density using a minimum of product. During drilling, the hydrostatic pressure exerted by the mud must be greater at any point in the area than that of the fluids contained in the rock so that they do not enter the borehole in the event of the pumps stopping when the mud is in circulation phase. Weighting agents are generally insoluble minerals with a high density such as barite (barium sulphate), calcium carbonate, ilmenite, hematite or galena (lead sulphide). The latter is no longer used due to its high toxic power. In this study, we used calcium carbonate CaCo3, it can increase the density of the mud up to about 1.44 kg/m3 and has the advantage of being soluble in hydrochloric acid compared to other weighting agents used, d where its interest in cleaning the well by acidification of the cake and as a completion fluid comes from. Calcium carbonate is in the form of a white powder, its melting point is 825°C, it is almost insoluble in water at 20°C and its pH is almost equal to 9.3 for 50 g/l .

2.1.4 Potassium chloride (KCL)

Drilling muds are subject to physico-chemical variations during the crossing of the different geological layers. These variations can alter their rheological and physico-chemical properties, mainly following the hydration of the clays found in the drilled formations. The addition of salts is designed to address the problem of clay swelling that can result in well subsidence.

The problem of well stability in shale formations has frustrated engineers since the beginning of oil and gas drilling. Well instability is in fact the most significant technical problem in drilling and one of the greatest sources of lost time and cost complications [13] [14]. To solve this problem, the study of water/rock interactions was carried out and research led to the principle of osmosis. If the formation is saliferous, for there to be no transfer of salt from the rock to the fluid, the latter should contain salts or be saturated. Salts are very effective for the chemical control of shale, the most commonly used are potassium chloride, sodium chloride, ammonium chloride and calcium chloride. Thanks to their different cationic characteristics, they have a positive effect on controlling the stability of the well. Potassium chloride is often used in drilling muds whether freshwater or brine based. Usually, the components of brine-based sludges are potassium chloride, bentonite, cellulosic polymers, lignosulfonates and sodium hydroxide [15].

Potassium being the greatest source of normal radioactivity, it occurs in illite, feldspar, mica and some evaporite ores, hence the possibility of chemical phenomena when minerals meet. When drilling shale formations, the K+ ion is retained by the clays, thus inhibiting their swelling while the CL- ion remains in the mud drilling the rest of the formations. The hydrated shales following the increase in their masses fall to the bottom of the well, thus creating damage to the mud and the drilling.

To avoid these problems and ensure the balance of the mud in the shale formations, the concentration of K+ ions must be continuously maintained constant, in order to compensate for the consumption of the K+ ion by the clayey formation and this by adding KCl or a another source of potassium. Potassium chloride is used in drilling fluids for stabilizing shales and controlling swelling clays. Inhibition is achieved with KCL in two ways. The chloride ion (Cl-) provides for the entry of water into the matrix of clays by what is called "mass action". This is true only if the salts are KCL, sodium chloride (NaCl) or calcium chloride (CaCl2). Otherwise, the potassium reacts as an inhibitor by exchanging the Na+ or Ca+ found in natural clays. Since the potassium ion is small and powerful, it is ideally suited to reduce the spaces where water can cause clays to swell [16] At a temperature of 20°C, potassium chloride is soluble at 340 g/l and its pH is between 5.5 and 6.

2.1.5 Starch

Starch is an abundant raw material and currently of low cost, it has good rheological properties necessary for the drilling fluid. It occurs in granular form in the reserve organs of mature plants. Very little used in its native form, it finds many applications after hydrothermal transformations in various chemical food industries. Nevertheless, this temperature dependence is a major drawback for its application in drilling fluids where the downhole temperature can reach high values. But currently, thermal stability is improved through chemical cross-linking Starch is an additive that is used to reduce filtrate in water-based sludge. This product has a thermal stability of approximately 121°C. But it is subject to bacterial attack, unless it is protected by high salinity (in the case of salty mud) or by a suitable bactericide. Starches are polymers of the family of carbohydrates with general formulas C6 H10 o 5 The use of starch in drilling muds slightly increases the viscosity while effectively limiting the loss of fluid in the formations.

2.1.6 The biocide

The biocide or bactericide is a chemical agent whose role is to destroy the bacteria present in the drilling muds. The bactericide is generally used in water sludges containing starches and polymers which are particularly vulnerable to bacterial attack. The choice of bactericide, although limited, is important because it must not alter the chemical balance of the sludge. The most used bactericides in drilling muds are glutaraldehyde and other aldehydes [17]. Few studies have been carried out to determine effective bactericides that are not harmful to the environment , nevertheless paraformaldehyde is used as an antibacterial in water sludge containing starches, xanthan gum, guar gum and other polymers due to its efficiency, its high inoculating power and its stability over time. In this study, we used the polymerized form of formalin for its ease of dosing Formaldehyde with the chemical formula CH2O comes in two (02) forms: - Paraformaldehyde: trimer of formaldehyde with the chemical formula O-ch2 - O-ch2 - O -ch2 is a linear polymer of formalin. The polymerized form is a water-soluble white powder; dissolved in hot water, it becomes monomeric. - Pure formalin: contains the polymerized form, it is a commercial solution of 37% to 40%. This product is in the form of a clear liquid, soluble in fresh water and brines which facilitates its use in water-based drilling muds but insoluble in hydrocarbons, its density is 1.08 and its point flash is 60°C, its ignition temperature is 300°C and its boiling point is between 96 and 98°C. Its dilution leads to depolymerization For the dosage of paraformaldehyde, there is a method published by the A.P.I (titration test – see appendix)

2.1.7 Potassium hydroxide

The rheological phenomena governing drilling muds are greatly influenced by pH. The ability of a product to maintain a pH in various physico-chemical conditions depends on a few particularly important factors such as the rock/water reaction. The pH of the base mud, which is almost neutral or slightly alkaline, must be adjusted according to the geological layers crossed and changing the composition of the sludge. Knowledge of the pH for drilling muds is important for the following reasons: Some chemical treatments can only be effective in a given range of pH, barium carbonate used universally as a weighting agent will not be able to fight effectively against contamination by gypsum or anhydrite only for pH values between 9.2 and 9.5. The dispersion of clays is an increasing function of increasing pH and the effectiveness of organic thinners is increased with increasing pH. It is recommended to work with pH between 7 and 10. The pH must be constantly checked and corrected if necessary. Checking its value makes it possible to quickly detect certain contaminations of the mud by the ground or the drilling waters and by the cementations. The latter give a pH of 11.5 to 12.5, while the pH for new sludge is between 7 and 9.5.

2.1.8 Clays

HMP (High Mod Prima) is the most used clay, it contains kaolinite, illite and quartz. Its role is to simulate drill cuttings. Containing several different components that will be found in geological formations, it would be possible to see how this clay will react with the formulations studied. When they absorb water, most clays swell and the water molecules fill the voids, thus changing the characteristics of the suspensions studied.

2.1.9 Biopolymers

The polymer is a chain of several molecules of the same compound which can provide several functions in the drilling muds. Indeed a polymer having a large molecular mass can be a flocculant, whereas the same type of polymer having a small mass can be a deflocculant. Environmental concerns have prompted researchers to develop biodegradable drilling muds rather than these synthetic muds**.**

2.2 Sludge preparation

The method of preparation of the fluids used follows a systematic sequence in order to obtain reproducible fluids. The preparation conditions are strictly identical.

2.3 Example of a formulations used

2.3.1 Diesel-based drilling mud formulation

They have formulated an oil-based drilling mud that has interesting characteristics for drillers, it has good rheological properties, and temperature stable.

Taking into account the literature, the common proportions of the constituent elements of a sludge oil (whose oil/water ratio is 85/15 by volume) are :

Table 2-1 : The common proportions of the constituent elements of a sludge oil

Elements	% weight	role
diesel fuel	63,7	Continuous phase
lime	2,9	Saponifier
Versamul	1,5	Main emulsifier
Versacoat	1,2	Emulsifier secondary
Versatrol	1,2	Filtrate reducer
VG69	0,6	Filtrate reducer Viscosifier (clay organophile)
$CaCO_3$	7,3	clogging
H_2O	16,3	Brine
NaCl	5,5	

The preparation of the sludge is carried out according to the following steps:

a) Diesel oil and emulsifiers are mixed for 15 minutes at stirring speed of 400 rpm.

b) Addition of viscosifier (VG 69) to the mixture which is stirred for Sminutes at a speed agitation of 400 rpm.

c) Addition of the filtrate reducer (Versatrol) to the mixture which is stirred at for 5 minutes at a speed of 400 rpm.

d) Addition of lime, to the mixture which is stirred for Sminutes at a speed of 400 revolutions/min.

e) Addition of brine to the mixture which is stirred for 15 minutes at a speed of 400 rpm.

Leave to age for 24 hours (The sludge must be left in a rotating sludge cell in hot rolling for 16 hours).

They determined the density and the rheological characteristics of the mud (plastic and apparent viscosities), the values of which are summarized in Table 2-2.

Table 2-2 : Rheological characteristics of oil-based mud before and after aging.

Characteristics of the sludge before aging	Characteristics of the sludge after aging
Density: 0.93 Lftoo :24 LSOO: 13.5 L200:10 LIOO;6 L6:2 L3: 1.5 Vp -24-13.5=iO.5centipoise Va= 24/2=12 centipoise	Density: 0.96 LOOO:24 L3oo: 13 L20o: 10 LIOO: 5.5 L6:2 L3:2 Vp =24-13=11 centipoise Va=24/2=12 centipoise

They noted that the greater the density, the greater the pressure exerted by the column of mud on the bottom and walls of the well is strong. The greater the differential pressure between the pressures of the deposits (pore) and the mud column is large, the higher the level rock accounting of the size is high. This alters the drillability of the land.

As far as the viscosity is concerned, the higher it is, the better the evacuation of the cuttings at from the bottom. Its increase makes the circulation pressure greater, which alters the operation of the bit, reduces advancement and mechanical speed.

This formulation was made to determine the density and characteristics rheological characteristics of the mud which must be preserved or even improved during the formulation an oil-based mud (oil/water ratio=85/l 5) based on the same diesel oil studied but deflavored [18].

General Conclusion

The field of drilling muds is vast and requires more in-depth studies. From this modest work, we can see that the properties rheological vary significantly with any variation that affects the base formulation or a product falling within the latter whether in quantity or quality.

The main objective of this work was to discover the state of the art of drilling fluids and to arrive at a characterization of the rheological properties of the different formulations of water-based and oil-based drilling muds, and finally to detail the role of the different additives used mainly in the formulations of drilling muds.

Annexe A

A.1 Titration tast

Titration: Chemical analysis by titration is used to test drilling fluids. A chemical reagent fills the pipette to level 0, then the reagent is released using the drop by drop. When the desired reaction is observed (eg color change, effervescence...), the level remaining in the pipette is recorded for the assay.

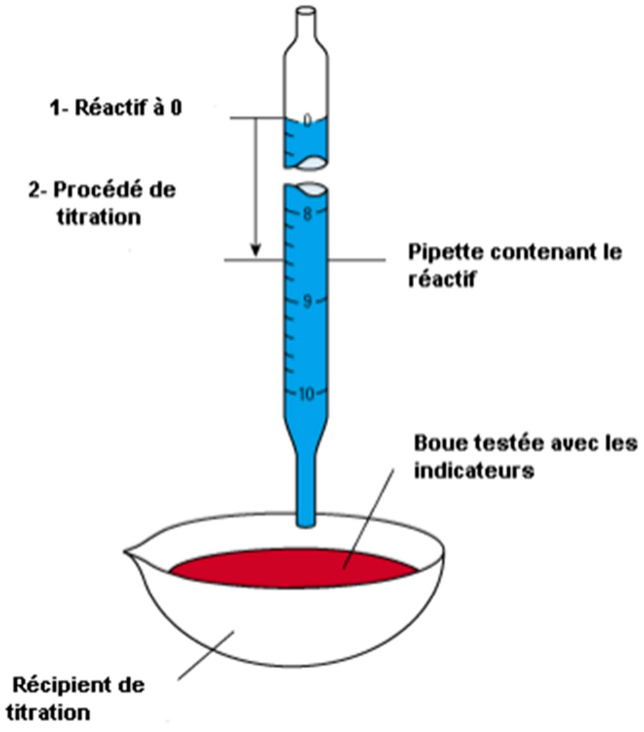

Figure 2-1 Titration test

Bibliography

[1] H. C. H. e. G. Darley, G.R. , "Composition and properties of drilling and completion fluids," *Gulf Professional Publishing, Houston,* p. 630, 1988.

[2] Khodja.M, "Etude des performances et Considérations environnementales," *Université Louis Pasteur Strasbourg - France,* 2008.

[3] *http://repository.enp.edu.dz/jspui/bitstream/123456789/495/1/BOUZEGAG.Chafai.pdf*

[4] C. e. P. Garcia, P, "Boues de forage," *Ed. Technip, Paris,* p. 189, 1968.

[5] M. Z. e. M. Stephens, "petroleum well construction. ," *edition John Wiley & sons,* 1998.

[6] B. Herzhaft, "un exemple de fluides complexes industriels," *Marne-la-Vallée France,* 2001.

[7] "Product data manual," 1988.

[8] K. M. C. J. P. F. e. Khodja-Saber, "Une nouvelle méthode pour l'évaluation de l'inhibition de la dispersion des argiles par les fluides de forage " *Journal de Formulation Français* 2008.

[9] R. C. G. e. C. V, "Drilling fluids : state of the art," *Journal of petroleum science and engineering,* 1996.

[10] E. M. J. e. al, "Petroleum well construction," *édition John wiley and sons,* 1988.

[11] J. A. R. C. R. A. A. H. Texas, "Personal communication from Ayers," *Argonne National Laboratory, Washington, D.C,* june 26 1994.

[12] D. B. B. T. a. D. I.M.T, "Oil exploration and production: Impact on the North Sea.," *Oil.Chem. Pollut,* 1986 1987.

[13] H. Van Oort E., A.H.Mody F.K, "Transport in shales and the design of improved water-based shale drilling fluids," *SPEDC,* 1996.

[14] F. K. A.H. and Mody, "''Critical parameters in modeling the chemical aspects of borehole stability in shales and in designing improved waterbased shale drilling fluids," *SPE28309,* 1994 1996.

[15] P. E. Ltd, "Groundwater Resources Protection From Drilling Waste, Northwest Territories and Yukon," *Dans Environmental Studies, no 62 .Préparé pour la Division des ressources hydrauliques de la Direction générale des ressources naturelles et du développement économique du MAINC,* 1988.

[16] J. I. Farina, "Produccio´n de escleroglucano por Sclerotium rolfsii," *Universidad de Tucuma´n, Argentina* 1997.

[17] D. T. Boehm P.D, A.Ravel, D.Caudle, D.French, N.Rabalais, R.Spies and J.Johnson, "Deepwater Program Literature Review Environmental Risks of Chemical Products Used in Gulf of Mexico Deepwater Oil and Gas Operations," *Vol.1. Technical Report. OCS Study MMS 2001-011.U.S.Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region , New Orlans, LA,* 2001.

[18] *(http://repository.enp.edu.dz/jspui/bitstream/123456789/5650/1/KHIRANI.Sarah.pdf.*