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BASICS OF DRILLING FLUID

EDITED BY
Dr. Deepjyoti Mech

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Preface

In petroleum engineering, drilling mud—also known as drilling fluid—is a thick, viscous fluid combination used in oil and gas drilling operations to cool and lubricate the drill bit as well as transport rock shavings to the surface. By exerting hydrostatic pressure, the drilling mud also helps to stop the possible incursion of water from water-bearing layers and the collapse of unstable strata into the borehole.

Water, whether fresh water, ocean, naturally occurring brines, or artificial brines, is the conventional foundation for drilling muds. Many muds are oil-based, using mineral or diesel oil, which are direct byproducts of the petroleum refining process, as the fluid matrix. Furthermore, other "synthetic-based" muds are created utilizing highly refined fluid components that are created to more strict property standards than conventional petroleum-based oils. Oil-based muds are better for drilling at deeper depths or in directional or horizontal drilling, which puts more strain on the drilling apparatus. In general, water-based muds are suitable for the less-demanding drilling of typical vertical wells at medium depths. Oil-based fluids raised environmental concerns, leading to the development of synthetic-based muds. However, the composition of all drilling muds is strictly regulated, and in some situations, certain combinations are not allowed to be used in certain settings.

A common water-based drilling mud also includes a mineral like barite (barium sulphate) to raise the weight of the column and stabilize the borehole, as well as a clay, typically bentonite, to give it enough viscosity to convey cutting chips to the surface. Smaller amounts of hundreds of additional ingredients may also be used, including salts like potassium chloride to prevent water from the drilling fluid from seeping into the rock formation and caustic soda (sodium hydroxide) to increase alkalinity and reduce corrosion. Water (often a brine), bentonite and barite for viscosity and weight, as well as a number of emulsifiers and detergents for lubricity, are all ingredients in oil- and synthetic-based muds.

Pumping drilling mud down the hollow drill pipe to the drill bit causes it to break free and flush back up the borehole to the surface. Oil- and synthetic-based muds are typically cleaned and recirculated for financial and environmental reasons (although some muds, particularly water-based muds, can be released into the environment in a controlled manner). The returning mud is sent through one or more vibrating screens to remove larger drill cuttings, and occasionally centrifuges are used to remove finer cuttings. For reuse down the borehole, cleaned mud is combined with fresh mud. Water well drilling also makes use of drilling fluids. The functions of drilling fluid, which are critical to the drilling process, are: (1) aid formation stability and productivity; (2) clean the bottom of the hole; (3) lift formation cuttings to the surface; (4) suspend cuttings while circulation is stopped; (5) cool the bit; (6) control subsurface pressure. This book presents the basics of drilling fluid for various applications.

Dr. Deepjyoti Mech
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CHAPTER -1

INTRODUCTION TO DRILLING OPERATION

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In order to create a circular cross-sectional hole in solid materials, a drill bit is spun throughout the drilling operation. Typically, the drill bit is a multi-pointed, rotating cutting instrument. At speeds ranging from hundreds to thousands of revolutions per minute, the bit is turned while being forced on the workpiece. By pressing the cutting edge against the workpiece, this prevents chips (swarf) from exiting the hole while it is being drilled.

Although the bit is often spun during rock drilling, the hole is typically not produced by a circular cutting action. Instead, the hole is often created by swiftly repeating small motions while driving a drill bit into the hole. Hammering may be done from within the hole (top-hammer drill) or from outside the hole (down-the-hole drill, DTH). Drifter drills are drills used to drill horizontally.

Drilled holes are distinguished by having a sharp edge on the entry side and burrs on the exit side (unless they have been removed). Additionally, the inside of the hole often bears helical feed marks. By generating extremely small layers of highly strained and disturbed material on the freshly formed surface and low residual stresses surrounding the hole opening, drilling may have an impact on the workpiece's mechanical characteristics. As a result, the workpiece is more prone to corrosion and fracture growth at the stressed surface. To prevent these harmful circumstances, a completion procedure may be performed.

Any chips are removed from fluted drill bits by the flutes. Depending on the material and processing conditions, chips may take the shape of microscopic flakes or lengthy spirals. The sort of chips that are produced may be used as a gauge for a material's machinability; lengthy chips indicate high machinability.

Drilled holes have to be positioned as perpendicular to the workpiece surface as practicable. This reduces the drill bit's propensity to "wander," or be diverted from the bore's intended centerline and result in an erroneous placement of the hole. The propensity to wander increases as the length-to-diameter ratio of the drill bit increases. Additionally, there are several additional techniques to prevent the inclination to walk, including:

1. Putting in place a centering mark or feature before drilling, such as by: Casting, moulding, or forging a mark into the workpiece
2. Middle punching
3. Spot drilling (i.e., centre drilling)

Spot facing, which involves milling a specific region of a casting or forging to create an exact location face on an otherwise rough surface [1]–[3]

Using a drill jig with drill bushings to constrain the drill bit's location. Drilling can create a surface polish of 32 to 500 microinches. Roughing will be around 500 microinches, and finish cuts will provide surfaces about 32 microinches. Cutting fluid is often used to boost speeds and feeds, improve surface polish, cool the drill bit, extend tool life, raise surface smoothness, and help expel chips. These fluids are often applied by spraying a fine mist over the workpiece or by flooding it with coolant and lubricant.

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It's crucial to take the work at hand into account and assess which drill would best complete it when choosing which drill(s) to employ. There are several drill designs, each of which has a specific function. The subland drill may drill holes of different diameters. For drilling bigger holes, use a spade drill. Chip management is made easier with the indexable drill.

Energy has been referred to as the ability to do labour (a concept used by Thomas Young in 1807). The two laws of thermodynamics explain the behaviour of energy. Early people just needed food and fuel for fires to cook and stay warm for most of the time. We use 110 times more energy per person now than we did in prehistoric times. Energy is a necessary component of modern economic growth and quality-of-life enhancement. A fuel is a substance that can store energy. Energy resources include all types of fuels utilised in the contemporary world, including those that may create electrical energy, move items, provide heat, and power many aspects of life [4]–[6].

Without energy, life is unimaginable. For growth, energy is a crucial input. Energy is needed for lighting, cooling, and heating in buildings as well as for residential, industrial, mining, and agricultural needs. While the need for energy in emerging nations is rising, developed countries continue to use enormous quantities of it. Energy resources will be much more in demand as a result of expanding populations and rising standards of life for many people in emerging nations. Fossil fuels will continue to be the major source of energy for the world as demand rises. The main energy sources are gas, coal, and oil. Fossil fuels account for around 80% of the world's energy production. However, France generates enough nuclear energy to fulfil 70% of the needs of the nation. Energy consumption is anticipated to rise by 50% between 2005 and 2030, while energy demands are estimated to rise by 55%.

Drilling is an essential part of the process of locating and using energy resources. When drilling a borehole, many fluids are employed. The chemical and physical compatibility of these fluids with the reservoir rock is the most crucial aspect in optimising output. Most drilling firms and authors prefer to use the phrase "fluids." Drilling mud or drilling fluid is the term for the circulating fluid used in drilling to carry out different drilling procedures. According to the "Baker Hughes drilling fluids" reference, a drilling fluid is a fluid that has been chemically prepared to have certain chemical and physical properties for circulation during the rotary drilling process.

Coal, petroleum products, natural gas, and electricity make up the majority of India's commercial energy sources. In addition to commercial energy, a lot of non-commercial energy sources are employed, including firewood, animal and agricultural waste, human and animal-powered draught, and animal and human power. The major causes of this increase include a rise in population coupled with increased urbanisation, along with the associated structural shift of economic growth. The major user of energy is the industrial sector, which uses roughly 50% of the nation's total commercial energy output. The transportation industry consumes the most petroleum products, mostly in the form of high-speed diesel and gasoline. The agricultural industry now consumes more commercial energy due to increased mechanisation and modernization of its operations.

The productivity of the well may progressively decrease as soon as the fluids begin to promote formation damage in various ways. Additionally, drilling fluids are maintained at a higher pressure than the formation pressure to prevent formation fluids from invading the drilling fluids. By obstructing the pores, the polymer particles, drilling cuttings, and compositional solids in drilling fluid have the potential to decrease rock permeability. The clay envelope in the pay zone particles will hydrate as a result of the filtrate's chemical reaction with the formation minerals, which will mobilise and then re-deposit the formation minerals. Scales produced as a result of this chemical reaction with the formation minerals will also reduce the permeability of the formation. The interchange of fluids between the well and the rock formation as well as solid intrusion into the formation must thus constantly be minimised. For this, we often add particulate material to the drilling fluid; this causes the creation of a low permeability filter cake, which helps to prevent the invasion of minerals and solids; later, the cake must be removed in order to expand the flow area. In addition to the polymers that seal the walls of the borehole and have viscosity-reducing effects, acid-soluble particles are also added to NDDF to lessen fluid invasion and clogging.

Bibliography

[1] Q. Zhang and M. Y. Zhao, "Minimum time path planning of robotic manipulator in drilling/spot welding tasks," *J. Comput. Des. Eng.*, 2016, doi: 10.1016/j.jcde.2015.10.004.

[2] N. Liu and G. Wang, "Shale gas sweet spot identification and precise geo-steering drilling in Weiyuan Block of Sichuan Basin, SW China," *Shiyou Kantan Yu Kaifa/Petroleum Explor. Dev.*, 2016, doi: 10.11698/PED.2016.06.15.

[3] V. Sampson and A. Sampson, "Diagnosis and treatment options for anterior white spot lesions," *Br. Dent. J.*, 2020, doi: 10.1038/s41415-020-2057-x.

[4] C. B. de C. Lima, V. S. Pinto, L. G. Sobreira, R. N. Ferreira, D. G. Vieira, J. F. T. de Castro, and G. B. A. Lima, "Drilling centers maturity model evaluation based on integrated operation key elements: A case study from Brazil," *Open Pet. Eng. J.*, 2016, doi: 10.2174/1874834101609010313.

[5] K. Liu, F. Chen, T. Zhu, Y. Wu, and M. Sun, "Compensation for spindle's axial thermal growth based on temperature variation on vertical machine tools," *Adv. Mech. Eng.*, 2016, doi: 10.1177/1687814016657733.

[6] F. Hosseinzadeh, S. Hossain, C. E. Truman, and D. J. Smith, "Measurement and Prediction of Residual Stresses in Quenched Stainless Steel Components," *Exp. Mech.*, 2014, doi: 10.1007/s11340-014-9890-2.

CHAPTER - 2

DRILLING FLUIDS AND THEIR TYPES

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Drilling fluid, considered the "blood" of drilling engineering and it is one of the key factors for successful drilling. Drilling fluid is important for obtaining information about the wellbore, to cool and lubricate the drill string, to reduce the formation damage, to prevent the well control issues & transporting drilled cuttings from the well bore to the surface. To perform the above functions various additives are added to the drilling fluid. There are two types of drilling fluid, WBM (Water based drilling mud) & OBM (oil based drilling mud).

WBM is commonly used drilling mud type. An oil well's productivity is focused on the control over formation damage during drilling. If the formation damage is least, more oil can be produced. The use of convectional water-based mud in water sensitive clays and shale formations may cause wellbore instability, formation damage, torque & drag, stuck pipe, logging and primary cementation failures, borehole washouts etc. These problems may become even more dangerous in directional or horizontal wells [1]–[3]. The alternative option of oil based mud is not capable of being done due to the severe environmental rules and regulations and also it's not economically feasible. The main cause of formation damage is solid invasion. Fine particles penetrate deep to the formation and are not removed easily by back-flushing.

There are three basic kinds of drilling fluids: air, muds with an oil basis, and muds with a water base. Only a few, extremely particular applications call for the use of air drilling fluids like mist, foams, and stiff foams.

Water-based muds

The most popular mud method is one that uses water-based drilling fluids. In certain unique sorts of systems, they are virtually as shale inhibitive as oil muds, but they are often less costly and easier to manage. However, tension is unavoidably reduced throughout the hole-drilling process in cemented formations [4]–[6]. The mechanical characteristics of the rock will alter if a water-based fluid is utilised since water has a tendency to seep into the formation. The instability of the borehole and damage to the formation may result from these changes alone. By utilising an inhibited water-based fluid, these harmful effects may be reduced. The two main types of water-based muds are dispersed and non-dispersed muds.

Dispersed Muds

In order to deflocculate the mud solids in these muds, a chemical dispersant has been introduced to the system. The majority of chemical dispersants in use (such as lignite and lignosulfonate) are acidic and need an alkaline atmosphere to operate well. High pH muds are the most contamination- and solids-tolerant of all the water-based muds. Without a question, they are the easiest of the water muds to manage. As a viscosifier and fluid loss agent, clay (bentonite) is used. In order to reduce fluid losses, dispersants are used to let adequate clay enter the system. The pH is controlled using caustic soda ($NaOH$), and the density is changed by adding weight components. The two subcategories of dispersed muds are calcium-based and saltwater muds. Calcium-based – Mud made of calcium maintains a desired level of calcium in the water phase. Using gypsum ($CaSO_4$) or lime [$Ca(OH)_2$], the calcium content may be kept constant.

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Compared to a fluid distributed in freshwater, these muds are more inhibitive and can withstand contamination with anhydrite and cement. Their thermal constraint is, however, significantly lessened.

Saltwater based—for standard dispersed fluids to operate well in seawater muds, the top limit is 20,000 mg/L chlorides (which is the salinity of seawater). This kind of system costs a little more than a freshwater system does. However, in offshore settings, this expense is made up by enabling muds to be transported in natural saltwater rather than freshwater.

Non-dispersed muds

Dispersants are absent in nondispersed muds, which is a key distinction between them and dispersed muds. A higher pH is not necessary for nondispersed drilling muds. They are less resistant to contaminants and solids since there isn't a dispersion present. Polymers are primarily used to limit fluid loss and preserve viscosity, however they are very prone to contamination by generated gases, fluids, and fluids from the formation.

Oil-based muds

Oil-based muds were created to stop water from penetrating the pore spaces and harming the formation. This kind of mud system has a number of benefits and drawbacks. These are some of the benefits:

Shale inhibition: The borehole retains stability in strongly smectitic or "gumbo" shales, and cuttings samples are often unharmed. The holes and the tubulars are moistened with a lubricant since oil is the continuous phase. In deviated wellbores, this is a clear benefit.

Thermal stability: Oil-based muds that have BHTs of 585 °F have proven stable in wells.

Resistance to chemical taint Carbonate, evaporite, and salt formations have no negative effects on an oil mud's characteristics. With the addition of lime, CO_2 and H_2S may be readily eliminated ($CaCO_3$).

The following are some drawbacks of oil-based mud systems:

High initial cost: The cost of a barrel of oil mud's oil fraction alone may range from $40 to $70 per barrel. This is far higher than the majority of water-based muds, regardless of weight. In the past, oil muds have generally had slower rates of penetration than water-based muds. Environmental limitations are present in the majority of locations where oil muds are employed. To manage full mud without dumping, clean up oil mud cuts, and limit any leaks, rig adjustments may be required.

Before disposal, oil mud cuttings may need to be cleaned up. Cuttings must be transferred to an authorised disposal site, according to several regulatory organisations. In oil muds, H_2S, CO_2, and CH_4 are soluble. Gas may become solution under pressure if it penetrates the wellbore. The gas may quickly escape solution at the bubble point and quickly exit the wellbore as it goes up the wellbore, carrying the mud with it. Not all wireline logs should be run in muds that contain oil.

Bibliography

[1] D. S. Ibrahim, N. A. Sami, and N. Balasubramanian, “Effect of barite and gas oil drilling fluid additives on the reservoir rock characteristics,” *J. Pet. Explor. Prod. Technol.*, 2017, doi: 10.1007/s13202-016-0258-2.

[2] M. V. Kok, “Characterization and development of drilling fluid type for an oil field,”

Energy Sources, Part A Recover. Util. Environ. Eff., 2010, doi: 10.1080/15567030801909433.

[3] R. Ikram, B. M. Jan, J. Vejpravova, M. I. Choudhary, and Z. Z. Chowdhury, "Recent advances of graphene-derived nanocomposites in water-based drilling fluids," *Nanomaterials*. 2020. doi: 10.3390/nano10102004.

[4] M. I. Abduo, A. S. Dahab, H. Abuseda, A. M. AbdulAziz, and M. S. Elhossieny, "Comparative study of using Water-Based mud containing Multiwall Carbon Nanotubes versus Oil-Based mud in HPHT fields," *Egypt. J. Pet.*, 2016, doi: 10.1016/j.ejpe.2015.10.008.

[5] O. E. Agwu, J. U. Akpabio, and G. W. Archibong, "Rice husk and saw dust as filter loss control agents for water-based muds," *Heliyon*, 2019, doi: 10.1016/j.heliyon.2019.e02059.

[6] E. U. Akpan, G. C. Enyi, and G. G. Nasr, "Enhancing the performance of xanthan gum in water-based mud systems using an environmentally friendly biopolymer," *Journal of Petroleum Exploration and Production Technology*. 2020. doi: 10.1007/s13202-020-00837-0.

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CHAPTER - 3

NON-DAMAGING DRILLING FLUID (NDDF)

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Non-damaging drilling fluid (NDDF) is a mud solution used often in pay zone sections to reduce formation damage. It doesn't include clay or barite. It is a method for increasing oil production from a well by reducing formation damage. NDDF was included in the Asset for drilling pay zones in the Linch field of the Mehsana block. There are many different particle sizes used. Its systems use long-chain, high-molecular-weight polymers that either prevent dispersion or coat the shale to obstruct it. They also increase viscosity and reduce fluid loss. Dehydration quickly seals up the permeable channels leading to the pay zone by transforming these particles into a firmly compacted, very impermeable mud covering on top of the rocks. Utilizing NDDF is the most efficient approach to stop drilling formation damage [1]–[3].

The NDDF formulation of three wells in the Linch field was optimised in the field, and the outcomes in terms of compatible mud properties have been promising. Testing and drilling went off without a hitch, and gauge holes showed high-quality logs. The wells' oil production productivity has increased dramatically as a result of their quick activation. In the North Cambay Basin of India, where NDDF marks a basic adjustment in strategy, Mehsana Asset of ONGC gives increased oil production while using contemporary technology specific attention. The distribution of bridging particle sizes must be carefully taken into account when designing a drilling mud. Mud with the proper particle sizes will function effectively to minimise fluid loss from the formation and solid invasion into its pores. Formation plugging by drill cuttings, drilling fluid compositional solids like clay, and polymer particles, change in wettability by filtrate, mud invasion into pay zone due to induced lost circulation, formation of scales as a result of chemical reactions between the formation minerals and mud filtrates, mud circulation rate, over balanced pressure, concentration of mud solids, and rheology are the main contributing factors to formation damage brought on by solid invasion.

The ideal fluid should

(a) Contain materials of specialised sizes to cover all exposed pore openings,
(b) Retain all pertinent drilling fluid characteristics,
(c) Lessen formation damage, lower well costs, and maximise production without disregarding HSE regulations,
(d) Have a minimum amount of drilled fine solids, reduced filtration loss, and filtrate should not undergo chemical reprocessing. All of the aforementioned characteristics are present in non-damaging drilling fluid (NDDF), which makes it the best fluid for controlling formation damage during drilling.

An oil well's productivity relies on how well forming damage is controlled during well drilling for a specific geology, well shape, and production method. Oil production is anticipated to be higher in a formation with less damage. Although all productive reservoirs are vulnerable to forming degradation, sandstone is far more sensitive to the effects of well bore fluids as lime stone, that produces via a fracture process [4]–[6]. Disruption to the pay zone due to improper drilling fluid composition and parameters may affect the oil output from a newly drilled well.

Following is a summary of the many primary processes of formation degradation caused by drilling fluid:

- Formation clogging caused by the compositional solids in drilling fluid, such as clay
- Drilled cuttings (drilled fines dissolved in drilling fluid) clogging a formation
- Formation clogging by particles of polymers
- Filtrate hydration of the clay shell that surrounds the pay zone particles. Fine particles that may block the formation pores are also produced as a result of the clay envelope's consequential dispersion.
- Filtrate-Induced Wettability Change
- Complete mud invasion into the pay zone since the circulation was cut off
- Scales are produced as a result of a chemical interaction between the mud filtrate and the formation fluid.

A perfect productive drilling fluid must include the aforementioned processes to fight formation damaging mechanisms.

- Non-degradable compositional fine particles, such as clay, barite, etc., should not be used.
- Minimal drill-through fine solids
- Successfully preventing the entry of polymer particles into the pay zone
- Dispersant in mud should not be used, and inhibitive filtrate should not enlarge the clay envelop surrounding pay zone particles.
- Lessening of filtering loss
- The least amount of progressive gelation is necessary to prevent the complete muck from invading during journeys and gel break circulations.
- Filtrate and formation fluid do not chemically react to produce an insoluble precipitate.

When drilling, Non Damaging Drilling Fluid (NDDF) supplies all of the aforementioned formation-damage-control components. It was intended to be utilised for all of the development wells in the ONGC Mehsana Asset (North Cambay Basin). The Asset, which already produces the most onshore oil for ONGC, places a strong emphasis on doing all in its power to maximise the amount of oil that can be extracted from its fields.

Modern technology is being used for asset management in this effort. Oil is produced from the multi-layered Mandhali, Mehsana, Linch, and Kalol Pays reservoirs, which have depths ranging from 2200 metres to 900 metres, at a rate of around 6600 TPD. The principal agricultural areas include North Kadi, Santhal, Sobhasan, Balol, Nandasan, Linch, Jotana, Becharaji, and Lanwa. Mehsana Asset formerly used traditional distributed mud systems. As shown below, NDDF prevents formation damage and has clear benefits over traditional scattered muds. The oil route from reservoir to well becomes blocked by tiny conventional mud particles that penetrate deeply into the formation.

1. Fine solids are absent from NDDF (clay). The addition XC polymer, which is biodegradable, provides thixotrophy, the most important characteristic of drilling fluid.
2. The clay encasing the pay zone's sand particles swells due to mud filtrate. The oil flow is impeded by this. Clay swelling is prevented by NDDF because it produces saline inhibitive filtrate.
3. In NDDF, appropriately sized calcium carbonate ($CaCO_3$) particles bridge the pore mouths on the formation surface to create an external filter cake. By drawing down, it is considerably simpler to remove an exterior filtercake than an interior one that is within the forming matrix.

4. Calcium carbonate is also utilised (instead of barites, which are used in traditional muds) to give NDDF a greater specific gravity. Because calcium carbonate is acid soluble, it may be eliminated later.
5. The presence of a dispersant causes tiny clay particles to develop within the matrix during the formation process. These particles then go on to block the pores. Since NDDF doesn't include any dispersant, blockage caused by dispersion-generated particulates doesn't occur.

Bibliography

[1] P. Talukdar and S. B. Gogoi, "A Study on the Role of Pre-Gelatinized Starch (PGS) in the Non Damaging Drilling Fluid (NDDF) for the Tipam Sand of Geleki Oilfield of Upper Assam Basin," *Int. J. Appl. Sci. Biotechnol.*, 2015, doi: 10.3126/ijasbt.v3i2.12552.

[2] S. Medhi, D. K. Gupta, and J. S. Sangwai, "Impact of zinc oxide nanoparticles on the rheological and fluid-loss properties, and the hydraulic performance of non-damaging drilling fluid," *J. Nat. Gas Sci. Eng.*, 2021, doi: 10.1016/j.jngse.2021.103834.

[3] S. Medhi, S. Chowdhury, D. K. Gupta, and A. Mazumdar, "An investigation on the effects of silica and copper oxide nanoparticles on rheological and fluid loss property of drilling fluids," *J. Pet. Explor. Prod. Technol.*, 2020, doi: 10.1007/s13202-019-0721-y.

[4] A. T. T. Al-Hameedi, H. H. Alkinani, S. Dunn-Norman, M. A. Al-Alwani, A. F. Alshammari, M. M. Alkhamis, R. A. Mutar, and W. H. Al-Bazzaz, "Experimental investigation of environmentally friendly drilling fluid additives (mandarin peels powder) to substitute the conventional chemicals used in water-based drilling fluid," *J. Pet. Explor. Prod. Technol.*, 2020, doi: 10.1007/s13202-019-0725-7.

[5] A. Saasen and J. D. Ytrehus, "Viscosity models for drilling fluids - Herschel-bulkley parameters and their use," *Energies*, 2020, doi: 10.3390/en13205271.

[6] A. T. T. Al-Hameedi, H. H. Alkinani, S. Dunn-Norman, M. M. Alkhamis, and J. D. Feliz, "Full-set measurements dataset for a water-based drilling fluid utilizing biodegradable environmentally friendly drilling fluid additives generated from waste," *Data Br.*, 2020, doi: 10.1016/j.dib.2019.104945.

CHAPTER - 4

ADVANTAGES OF NON-DAMAGING DRILLING FLUIDS

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Daily testing and ongoing supervision of drilling fluids by staff with specialised training is necessary. Any sort of fluid's paperwork makes it very apparent what safety risks come with handling it. In order to make sure that the formulations being used conform to the rules set up to preserve both the natural environment and the communities where drilling takes place, drilling fluids are also subject to stringent inspection by international regulatory organisations. The machinery used to process or pump fluid is continuously inspected at the rig site for symptoms of abrasion or chemical corrosion wear. To guarantee that safety is not jeopardised, elastomers used in blowout-prevention devices are evaluated for compatibility with the suggested drilling-fluid system [1]–[3]. Low-density water-based fluids are often used for drilling the top-hole portions (WBFs). The operator may transition to an OBF or SBF at a specified time in the drilling process depending on formation types, downhole temperatures, directional drilling plans, and other criteria. There are additional high-performance WBFs available to handle various drilling conditions.

The drilling-fluid system may be exposed to the following substances depending on the well's location:

Contamination may also occur while moving from one drilling-fluid system to another and when coming into contact with the spacers and cement slurries required to permanently fix casing. Any well will present operational and environmental issues, and drilling-fluid experts should be cognizant of these challenges when creating drilling-fluid programmes. Working closely with the operator, the specialist (who is often assisted by technical specialists and a research team) may create a programme that is both safe and economical while planning for the range of situations that are likely to be faced. Specific performance targets and the methods by which success will be judged are often established at the planning stage [3]–[5].

In comparison to traditional scattered muds, NDDF offers different benefits and minimises formation damage. Oil flow is obstructed by the clay envelopes that mud filtrate expands around the sand particles of the pay zone. Clay swelling is prevented by NDDF because it produces saline inhibitive filtrate. Conventional muds contain fine solids that penetrate deeply into the formation and are difficult to remove by back-flushing. These solids clog the oil passage from reservoir to well, and the presence of dispersants causes fine clay particles to form inside the formation.

These particles then move on to clog the pores. NDDF does not include fine particulates (clay), and the additive-XC polymer, which is biodegradable, gives drilling fluid its thixotropic properties. No blockage is caused by dispersion-generated particles since it is dispersant-free. An external filter cake is created when $CaCO3$ particles of the right size that are present in the NDDF cross the pore mouths on the formation surface. In order to reduce fluid loss and stop solids from the wellbore from invading the formation, external filter cakes are utilised. Compared to an internal filter cake that is within the forming matrix, an exterior filter cake is considerably simpler to remove. In order to provide NDDF a greater specific gravity, calcium

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carbonate is also added. In place of the barite used in traditional muds, calcium carbonate is acid soluble and may be removed afterwards.

NDDF has numerous advantages over conventional distributed muds, one of which is the reduction of formation damage.

1. The tiny particles of conventional muds block the oil's passage from the reservoir to the well deep into the formation. The NDDF has no fine solids (clay). Thixotrophy, the most crucial element of drilling fluid, is provided by the biodegradable ingredient XC polymer.

2. As mud filtrate moves through the pay zone, the clay envelopes around the sand particles expand. This causes a blockage in the oil flow. By producing saline inhibitive filtrate, NDDF prevents clay swelling.

3. NDDF bridges the pore mouths on the formation surface with properly selected calcium carbonate ($CaCO_3$) particles of the proper sizes to produce an external filter cake. It is far more difficult to remove internal filter cakes by drawdown than external filter cakes from the formation matrix.

4. Calcium carbonate is also utilised to increase the specific gravity of NDDF (instead of barites used in conventional muds). Calcium carbonate is acid soluble, therefore you can then remove it.

5. When the dispersant is present, the developing matrix generates tiny clay particles that plug the pores. Dispersion-produced fines don't create any blockages since NDDF doesn't include any dispersant.

As a result of the overbalance pressure, muck enters the formation and may harm the formation. Invading particles that were previously suspended in the drilling fluids may obstruct the pores, reducing the permeability of the rock. Mud filtrate may interact with formation minerals to mobilise in-situ particles and then cause them to redeposit, to swell the pay-zone clay, to change the reservoir rock's wettability, to generate emulsions that reduce permeability, and more. Greater output of hydrocarbon results in less harm. Therefore, in order to minimise formation damage, the following considerations should be made while developing a successful mud:

1. Reduce fluid loss, first.

2. Should not include dispersants and non-biodegradable fine particles to the mud, such as bentonite, barite, etc.

3. Reduce the amount of drilled-in fine particles in the mud.

4. Make inhibitive filtrate that won't enlarge the clay envelop in the formation particles and won't react with the formation fluid to produce insoluble precipitate.

The drilling-fluid employees assigned to the operation maintain:

1. Accurate documentation of test findings
2. Fluid volumes
3. Drilling activities
4. Product stock
5. Actions aimed towards obtaining environmental compliance

The typical drilling mud report displays the information that the drilling mud staff (commonly referred to as "mud engineers") at the rig site regularly deliver. These reports, which are often computer-generated and saved in a database, as well as the post-well study carried out at the end of the well, serve as reference materials for subsequent wells in the same region or wells that offer comparable issues.

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Bibliography

[1] J. L. B. Ribeiro, J. C. Queiroz, R. T. Lopes, M. J. Anjos, L. C. B. Bianco, A. R. D'Almeida, and E. F. Campos, "New methodology for analysis of performance for diverting agents in unconsolidated sandstones in real time with physical simulator using computed tomography," *Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip.*, 2007, doi: 10.1016/j.nima.2007.04.100.

[2] A. C. Perricone and W. C. Browning, "Formation clay chemistry," 1962. doi: 10.2523/433-ms.

[3] S. Batarseh, A. A. L. Harith, H. Othman, and H. Al-Badairy, "Flow enhancement by high power laser technology," 2019. doi: 10.2523/19308-ms.

[4] A. A. Liagova and I. A. Liagov, "The technology of completion reservoir by drilling a network of branched channels under controlled trajectory," 2019. doi: 10.1201/9780429327070-47.

[5] N. Hands, P. Francis, A. Whittle, and D. Rajasingam, "Optimizing inflow performance of a long multi-lateral offshore well in low permeability, gas bearing sandstone: K14-FB 102 case study," 1998. doi: 10.2118/50394-ms.

CHAPTER - 5

FUTURE DIRECTIONS IN PETROLEUM INDUSTRY

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The general public has recognised the petroleum business as one that has negatively impacted the environment as a result of using potentially harmful goods or potentially harmful methods in order to provide a sustainable flow of hydrocarbon energy. This encourages the industry to continue investing in R&D in order to develop technology and products that are environmentally friendly [1]–[3].

For each new technology or product, the current R&D trend is to develop sustainable processes and expertise. Drilling fluids are needed for oil and gas well drilling. Unfortunately, drilling fluids have become more complex in order to address the many operational demands and issues. The substances used in the process to improve the quality and performance of the drilling fluids damage underground and subterranean systems, landfills, and the surrounding environment. Drilling fluid technology must be reviewed in the context of the development of environmental consciousness and pressure from international environmental authorities in order to advance and enhance the petroleum sector's image as an ecologically benign enterprise.

Drilling fluid is a general term that may apply to any mixture used to make cuttings or remove them from a ground borehole. Drilling fluid is basically the most important component for digging the earth, especially when drilling for oil and gas. The drilling fluid is comparable to drilling because it may be compared to human blood. The basic components of drilling fluids are water, oil/gas, and chemical additives. These criteria provide the basis for the classification of drilling fluids. Mud is a mixture of several materials and a suspension of particles in either oil or water.

Future drilling fluid research should concentrate on developing a drilling fluid that is environmentally benign and has no harmful impacts on the environment. This is significant because, despite increasing instances of environmental pollution brought on by the release of drilling waste into the environment, the use of oil-based drilling fluids is being restricted by governmental and non-governmental organisations in many nations. OBM usage is thus highly controlled [4]–[6].

A large worldwide oil business used highly dearomatized aliphatic solvents to create a low-toxicity mud system. These formulations are highly expensive even if they have no adverse impact on the environment. It is surely challenging to lower their cost of formulation such that overall drilling expenses are lower.

Environmentally friendly mud additives

Defoamers, descalers, thinners, viscosifiers, lubricants, stabilisers, surfactants, and corrosion inhibitors have been shown to have hazardous impacts on marine and human life. Effects might include slight physiological adjustments, decreased fertility, and increased death rates. The survival and physiological reactions of fish eggs and fry were impacted by ferro-chrome lignosulfonate, a thinner and deflocculant. Fish fry are killed by the filtration control additive CMC (carboxymethylcellulose) at high concentrations (1000–2000 mg/ml), and physiological

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alterations begin at 12–50 mg/ml. However, corrosion inhibitors like phosphoxit-7, EKB-2-2, and EKB-6-2 harm human genetic development and induce teratogenic effects.

The release of 896 tonnes of drilling mud containing SOLTEX into the British shoreline is another illustration of the usage of a harmful chemical in OBM composition. When questioned, the business and the organisation in charge of monitoring the sector gave just the brand name of the drilling mud's active component, SOLTEX, without mentioning the fact that SOLTEX contained potentially harmful heavy metals, as Greenpeace reported in a 1995 article. According to information supplied in the product data sheet for specific chemicals, exposure to these compounds may result in cancer in a person. It is common knowledge that harmful chemicals work best. How will they be replaced, then? One of the issues scholars will face in the future is undoubtedly finding an answer to this question.

Sustainability

Despite significant advancements in technology, drilling fluid's position is still in a difficult environment if its status is evaluated in terms of sustainability. It is a result of the complicated mud system composition that is required to achieve the many requisite qualities for efficient drilling. The sustainability of the mud system is also affected by two problems:

1) Making sure that the base oils needed to make environmentally friendly mud systems are always available; and

2) Carrying out a full drilling programme in a way that is both safe and environmentally friendly. The researchers face a difficult environment as a result of these two problems. Instead of using traditional base oil, the startup should take into account eco-friendly base oils with zero toxicity. The sources are from plants where no harmful or hazardous substances are used during the whole procedure. These aims put researchers in a difficult position to accomplish their objectives. Another difficult task is to guarantee timely resource availability.

Extreme high temperature and high pressure (HTHP) conditions have a significant impact on mud systems made of macro- and micro-based components (chemicals and polymers). This is caused by the significant drop in gelling and viscous characteristics caused by the affiliation or breaking of polymer chains and branches by vibration, Brownian motion, and heat stress.

Nanomaterials with exceptional heat stability and pressure consistency should be developed to address this issue. In this article, a cutting-edge literature review has been done. It has been shown that WBDF, OBDF, and other drilling fluid types are not currently ecologically friendly. Though unsustainable, the OBDF is the best. As more stringent environmental regulations are implemented globally, using oil for exploration and production is becoming more challenging. The development of substitutes that will convert mud technology into a sustainable one has to be prioritised.

Nanotechnological advancements

Alternative mud additions including nano-silica, nano-graphene, and other nano-based compounds have been suggested. A mud system based on nanomaterials is one that has at least one ingredient with a particle size between one and one hundred nanometers. Mud systems may be categorised as either basic nano-mud systems or sophisticated nano-mud systems depending on how many nano-sized additives are present. It is anticipated that the use of nanomaterials in mud systems would lower the total solids and/or chemical content of these mud systems, hence lowering the overall cost of mud system development.

The primary material on the cell walls of trees and other plants is cellulose. Nano crystalline cellulose (NCC), which is considered to be the purest type, is used to stiffen and strengthen materials. Several Canadian oil corporations are now working together to do research into the

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potential use of NCC as a substitute drilling fluid addition in order to create a sustainable mud system.

Bibliography

[1] S. Varjani, R. Joshi, V. K. Srivastava, H. H. Ngo, and W. Guo, "Treatment of wastewater from petroleum industry: current practices and perspectives," *Environ. Sci. Pollut. Res.*, 2020, doi: 10.1007/s11356-019-04725-x.

[2] M. N. Agista, K. Guo, and Z. Yu, "A state-of-the-art review of nanoparticles application in petroleum with a focus on enhanced oil recovery," *Applied Sciences (Switzerland)*. 2018. doi: 10.3390/app8060871.

[3] G. Hu, J. Li, and G. Zeng, "Recent development in the treatment of oily sludge from petroleum industry: A review," *J. Hazard. Mater.*, 2013, doi: 10.1016/j.jhazmat.2013.07.069.

[4] K. Hui, J. Tang, H. Lu, B. Xi, C. Qu, and J. Li, "Status and prospect of oil recovery from oily sludge:A review," *Arabian Journal of Chemistry*. 2020. doi: 10.1016/j.arabjc.2020.06.009.

[5] R. W. Ahmad, K. Salah, R. Jayaraman, I. Yaqoob, and M. Omar, "Blockchain in oil and gas industry: Applications, challenges, and future trends," *Technol. Soc.*, 2022, doi: 10.1016/j.techsoc.2022.101941.

[6] J. Chen, W. Zhang, Z. Wan, S. Li, T. Huang, and Y. Fei, "Oil spills from global tankers: Status review and future governance," *Journal of Cleaner Production*. 2019. doi: 10.1016/j.jclepro.2019.04.020.

CHAPTER - 6

FUTURE AND DISADVANTAGES OF NON-DAMAGING DRILLING FLUID (NDDF)

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Conventional muds are known to harm the formation more, especially those that include bentonite. This is due to clay particles in the drilling fluid. The ideal situation would be one in which there is no formation damage, but this is not practical. A non-damaging drilling fluid (NDDF) without bentonite was created [1]–[3].

Even while it couldn't totally prevent formation damage, it was nevertheless able to reduce the amount of damage caused by drilling. The rheological characteristics of the fluid were determined using a variety of laboratory techniques. To further comprehend the features of the developed fluid, it was compared to another non-damaging drilling fluid. We studied both fluids throughout time to see how they changed. The pH of both fluids dropped with time, as was shown. While the viscosities of both liquids grew with time. The results of the static immersion tests and shale stability tests showed that groundnut husk was much less reactive with shales.

i) A non-damaging drilling fluid (NDDF) is less detrimental to formations than traditional drilling fluids since it is made without bentonite and barite.

ii) The formulated drilling fluid's rheological characteristics were identified.

iii) The probability of problems like borehole collapse, clogged pipes, etc. is reduced in shale formations for NDDF because shale spalling and swelling are less common. Due to less formation damage, it may be utilised to better advantage in pay zone portions and lowers the likelihood of production-related issues.

With the advancement of science and technology, every product or tool may be enhanced. The scenario with the drilling fluid is similar. In the future, many of the chemicals in this fluid may be replaced with cheaper substances that could also provide better effects than the current collection of additives [4]–[6].

A better polymer is employed to create a drilling fluid with a steady free pH. An organic material called groundnut husk was used as a polymer in the drilling fluid composition. Drilling fluids that are not hazardous include a range of biological elements. In the near future, they might be used to create better, non-harmful drilling fluids. Additionally, biopolymers are often inexpensive and may increase the drilling fluid's economic viability.

Due to increasing Deepwater drilling, the possibility of natural gas hydrate problems during drilling has grown in recent years. Because hydrate formation prefers high pressures and low temperatures, the deep ocean bottom offers the optimum environment for hydrate growth in water-based drilling muds. Recently, hydrates have been examined and recorded in many deep ocean locales.

Hydrates may harm water-based drilling muds in two different ways. The hydrates may first form a "plug" or solid mass within the wellbore. A low-circulation area, such as a choke line, a death line, or a recess within a blowout preventer, may be the origin of this obstruction. When formation starts, there is a chance that it may spread fast to other parts of the system. Because of their mechanical strength, hydrates in large quantities might prevent drill string rotation. The second method hydrates could become problematic is due to their chemical makeup. The drilling mud's water foundation provides the water needed for formation.

The flow characteristics are severely damaged by the water loss from the mud. In the worst scenario, all solids will settle out, leaving little or no fluid in the wellbore. It is quite difficult to retain effective control when so many problems are at once. Research has been done in recent years to better understand hydrate formation in drilling fluids and, eventually, to avoid it due to the possibility of such catastrophic repercussions.

Drilling fluid composition and properties are crucial in drilling operations. Clay minerals initially function as a good rheological adjuvant in drilling muds. However, drilling problems such plug development may occur due to oil reservoir contamination by clay minerals found in the drilled geological formation (Shales).

Examined are the rheological and filtration characteristics of water-based muds with varied polymer and electrolyte concentrations. The physical and chemical alterations of the drilled formation and the drilling fluid are examined during the drilling process. Based on the clay found in the geological formation, an optimal drilling fluid system using a unique filtration procedure is therefore provided.

Inhibition and filtration/rheological properties are closely related. As a consequence of a variable rate of penetration (ROP) ranging from 8 to 24 m/h, the findings show that major difficulties develop in the 12"1/4 (really 16") interphase and are detected at depths of 700-950 m. Lost circulation, especially in Turonian and Salt Senonian formations, shale instability, hole cleaning challenges brought on by lower annulus velocities in bigger hole sections, well caving, and collapse are just a few of the concerns that are covered.

There hasn't been any research or field testing on Algerian fields to determine how WBM affects drilling operations. OBM, which is now used in many places of Algeria, will be replaced by WBM. According to this scientist, the usage of WBM additives like polymer and KCl lowers Shale instability.

Clay wettability and inhibitory properties were examined using the behaviour of water-clay-polymer-electrolyte systems. These qualities are connected to rheological and filtration properties for both mud and filtrate. Understanding how the stability of the Shale plays is affected by adding salt to WBM depends critically on cuttings characterisation. Cuttings that have been recovered but contain drilling fluid contamination are cleaned. The cleaning of cuttings in solvent is advised by expert labs.

Washing may have advantageous effects like clogging, which reduces permeability and filtration, or adverse effects like contamination of Shale samples, which has a big influence on evaluating polymers. It's important to highlight the development of a prototype device for gathering and keeping drill cuttings in a clean, continuous stratigraphic sequence.

Bibliography

[1] S. Medhi, S. Chowdhury, N. Bhatt, D. K. Gupta, S. Rana, and J. S. Sangwai, “Analysis of high performing graphene oxide nanosheets based non-damaging drilling fluids through rheological measurements and CFD studies,” *Powder Technol.*, 2021, doi: 10.1016/j.powtec.2020.08.053.

[2] S. Medhi, D. K. Gupta, and J. S. Sangwai, “Impact of zinc oxide nanoparticles on the rheological and fluid-loss properties, and the hydraulic performance of non-damaging drilling fluid,” *J. Nat. Gas Sci. Eng.*, 2021, doi: 10.1016/j.jngse.2021.103834.

[3] P. Talukdar and S. B. Gogoi, “A Study on the Role of Pre-Gelatinized Starch (PGS) in the Non Damaging Drilling Fluid (NDDF) for the Tipam Sand of Geleki Oilfield of Upper Assam Basin,” *Int. J. Appl. Sci. Biotechnol.*, 2015, doi: 10.3126/ijasbt.v3i2.12552.

[4] . V. M., “EFFECT OF FLY ASH ON THE RHEOLOGICAL AND FILTRATION PROPERTIES OF WATER BASED DRILLING FLUIDS,” *Int. J. Res. Eng. Technol.*, 2013, doi: 10.15623/ijret.2013.0208025.

[5] H. C. Lau, H. Li, and S. Huang, “Challenges and Opportunities of Coalbed Methane Development in China,” *Energy and Fuels*. 2017. doi: 10.1021/acs.energyfuels.7b00656.

[6] A. K. Darwesh, T. M. Rasmussen, and N. Al-Ansari, “Kicks Controlling Techniques Efficiency in Term of Time,” *Engineering*, 2017, doi: 10.4236/eng.2017.95028.

CHAPTER - 7

INTRODUCTION TO NON DAMAGING DRILLING FLUID (NDDF)

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To avoid formation damage and ensure the integrity of the pay zone or reservoir, NDDF is indeed a polymer mud technique that does not include clay or barite. Long-chain, high-molecular-weight polymers are included into the systems to cover the shales to avoid dispersion, boost viscosity, and minimise fluid loss, or encapsulate drill materials to prevent dispersion. The particles combine while dehydrated to form a highly compacted, very impermeable mud coating on top of the rocks, which soon blocks the permeable routes into the pay zone. The oil pathway from the reservoirs to the well becomes blocked when fine particles from ordinary mud penetrate deeply into the rock. In NDDF, there are no fine solids (clay). Clay envelops surrounding the sand particles in the pay zone are enlarged by mud filtrate. The oil's movement is impeded by this. Clay swelling is stopped while NDDF creates a saline inhibitive filtrate. The presence of the dispersant causes the forming matrix to produce fine clay particles, which then go on to block the pores. No blockage is caused by dispersion-generated particles since NDDF is dispersant-free. A reservoir in a subsurface sand or rocky outcrop that used to generate oil or gas but is now utilised for natural gas storage is known as a depleted reservoir. Depleted oil and gas reservoirs, groundwater reservoirs, and salt cave diver reservoirs are the three categories into which underground reservoirs are divided. To decrease drilling and completion-induced damage, particularly in horizontal open pretty much the entire completions, the industry created new types of fluids in the early 1990s, such as drill-in fluids (DIF), which offered the same lubricity, suppression, solid suspension, and borehole stability as common drilling fluids. Solid materials were employed as weighing materials to regulate formation pressure for DIFs and also as bridging agents to fill the surface of the a formation matrix. The performance of a well is influenced by the solids content of both the drilling fluid, according to experience. The open hole worked better if the drill solid could've been maintained to a low concentration; if solid control was unable to be accomplished, substantial formation damage resulted. Non-Damaging Drilling Fluid were produced as a consequence. Natural gas injected into a depleted reservoir may be stored in the gaps between grains without moving or affecting nearby formations, allowing for later delivery at profitable rates. Depleted reservoirs are cheap and easy to build, operate, and maintain since geologists have previously studied their physical and geological characteristics [1]–[3].

The rock formation of a depleted reservoirs must be able to withstand the repeated cycles of pressure rise and fall during natural premixed combustion and production, respectively. The porosity and permeability of a depleted reservoir, its proximity to gas markets, and the existence of infrastructure suitable for injection and production are further factors that affect a depleted reservoir's economic viability. Due to the previously established geological imperviousness of depleted oil and natural gas fields, they may be used to store gas. Another advantage is that during prior exploration and production efforts, these reservoirs were carefully investigated. Furthermore, it would be feasible to employ current wells for retention operations provided the required conversion processes have been completed. Not all exhausted oil and gas reserves, nevertheless, can be turned into gas storage facilities. One of the qualifying requirements is the depth as well as the appropriate permeability and permeability of a reservoir rock. Facilities constructed with exhausted oil and gas fields are better suited for seasonal usage because of their restricted injection as well as withdrawal flexibility and lack of gas storage due to their reservoir engineering characteristics. Whenever the drilling fluid volume needed for well controls and wellbore stabilization is greater than the formations' capacity to withstand fracture, induced losses result. The problem of depleted reservoirs is distinct. Pore pressure decreases with decreasing reserves, weakening rocks that contain hydrocarbons. On the other hand, neighbouring or interbedded low permeability rocks maintain their pore pressure. Offshore activities worsen this situation because of how cooperation limits the capacity to stop mud leaks. If the low pressure gradient and fracture gradients levels required to drill the reservoir can be met by a drill-in fluid system, and when the fluid contains specifically designed lost circulation materials to successfully bridge or seal the formation [4]–[6]. The following describes the numerous chemicals we used in this study along with various drilling fluid additives:

Distilled Water

Because the drilling fluid in this project primarily water-based, water must also be the continuous phase. Water-based hydraulic fluid is used since it is more economical and ecologically benign.

Flaked $CaCO_3$ & Micronized $CaCO_3$

In drilling fluids, calcium carbonate ($CaCO_3$) is often utilised as a bridging ingredient and a weighing agent. $CaCO_3$ reduces the formation damage when it serves as a bridge ingredient. By sealing the holes in the formation and covering the permeable zones with a filter cake layer, it isolates those areas. This increases drilling mud density without minimizing formation damage and slightly lowering filtrate loss.

Polyanionic cellulose

Drilling fluids, sometimes referred to as muds, are sophisticated chemical mixtures that are used in oil and gas wells to control formation pressure, suspend formation clippings for transportation to the surface, and cool and lubricate mud bit operations. In order to lubricate, suspend clays from cutting, and alter the formation press throughout the pipe, PAC polyanionic cellulose is crucial. PAC Compositions are commonly changed to accommodate different activities by adding polyanionic cellulose. It works in the mud as a viscosifier as well as a weighing agent. Additionally, it lowers fluid loss and modifies ph. It is a chemical substance with a filtrate reduction that is often found in lubricants. In some of the most popular filtrate reducers, a little quantity pf viscosity PAC polyanionic polysaccharides chemical is used.

Biocides

The offshore oil and gas sector uses biocides to boost productivity by reducing corrosion and microbial-induced biofilm on equipment. The oil and gas industry takes care while using this chemical. To stop bacteria and other dangerous organisms from proliferating in the wellbore, it is used in small amounts. For the protection of equipment and greater operational effectiveness, microbial caused corrosion must be controlled. Biocides are effective in removing the bacteria-produced acids, scales, slime, and foul odors. Biocides may also help to keep the top structure from rusting. In order to stop bacterial development in pipelines, biocides are helpful. To prevent internal equipment from corroding during hydrostatic testing, biocides are advised. Insects, rodents, and other pests are stopped, while viruses, germs, and fungus are controlled by chemical or biological means by biocidal agents. They are also used to preserve commodities and safeguard humans and animals. Insect repellents, disinfectants, and wood preservatives are typical examples. A biocidal product will often include the "active agent" as well as a variety of compounds. The dangerous organism is controlled by the active ingredient.

Bibliography

[1] S. Medhi, S. Chowdhury, N. Bhatt, D. K. Gupta, S. Rana, and J. S. Sangwai, "Analysis of high performing graphene oxide nanosheets based non-damaging drilling fluids through rheological measurements and CFD studies," *Powder Technol.*, 2021, doi: 10.1016/j.powtec.2020.08.053.

[2] S. Medhi, D. K. Gupta, and J. S. Sangwai, "Impact of zinc oxide nanoparticles on the rheological and fluid-loss properties, and the hydraulic performance of non-damaging drilling fluid," *J. Nat. Gas Sci. Eng.*, 2021, doi: 10.1016/j.jngse.2021.103834.

[3] S. Medhi, S. Chowdhury, A. Kumar, D. K. Gupta, Z. Aswal, and J. S. Sangwai, "Zirconium oxide nanoparticle as an effective additive for non-damaging drilling fluid: A study through rheology and computational fluid dynamics investigation," *J. Pet. Sci. Eng.*, 2020, doi: 10.1016/j.petrol.2019.106826.

[4] S. Medhi, S. Chowdhury, D. K. Gupta, and A. Mazumdar, "An investigation on the effects of silica and copper oxide nanoparticles on rheological and fluid loss property of drilling fluids," *J. Pet. Explor. Prod. Technol.*, 2020, doi: 10.1007/s13202-019-0721-y.

[5] P. Talukdar and S. B. Gogoi, "A Study on the Role of Pre-Gelatinized Starch (PGS) in the Non Damaging Drilling Fluid (NDDF) for the Tipam Sand of Geleki Oilfield of Upper Assam Basin," *Int. J. Appl. Sci. Biotechnol.*, 2015, doi: 10.3126/ijasbt.v3i2.12552.

[6] D. Mech, B. M. Das, A. Sunil, M. Areekkan, and S. Imaad, "Formulation of a rice husk based non-damaging drilling fluid and its effect in shale formations," *Energy Clim. Chang.*, 2020, doi: 10.1016/j.egycc.2020.100007.

CHAPTER - 8

CONVENTIONAL DRILLING FLUID

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Although the terms "fluids" and "drilling muds" are sometimes used interchangeably, most drilling firms and writers prefer the word "fluids" due to its broader definition. Without putting any limitations on the composition or the qualities of the drilling fluids, this industry uses a number of classifications to characterize them. Here are a few examples of definitions that are accessible and come from various sources: The fluid that includes all of the compositions needed to facilitate the formation and removal of cuttings from an earthen well is referred to as a drilling fluid. According to the Baker Hughes Drilling Fluids Reference Guide, a drilling fluid is a fluid that has been chemically prepared to have certain physical and chemical properties for circulation during the rotary drilling process. The drilling fluid is a circulating fluid used during rotary drilling to carry out any or all of the many tasks necessary for drilling operations, according to the American Petroleum Institute (API). A drilling fluid is described as "any number of gaseous and liquid fluids and mixes of fluids and solids used throughout operations that drill boreholes into the ground" by the Schlumberger Oilfield Glossary. It is important to note that over the entire history of drilling, novel compositions and features of drilling fluids have been able to emerge thanks to the industry's adoption of a broad and restriction-free definition. One of the most crucial components of every drilling operation is drilling mud. The mud performs a variety of tasks that must all be optimized for safety and minimal overall issues. Failure of the mud to perform as intended may be very expensive in terms of time and resources, endanger the proper completion of the well, and possibly lead to serious issues like blocked pipes, kicks, or blowouts. Figure 1 depicts the three basic types of drilling fluids: gaseous drilling fluid, which may include a variety of gases, non-aqueous muds, often known as oil-based muds (OBs), and water-based muds (WBs), which can be either dispersed or non-dispersed [1]–[3]. These would be utilised for drilling different oil and gas formations together with their shortly after starting and the proper polymer and clay additives.

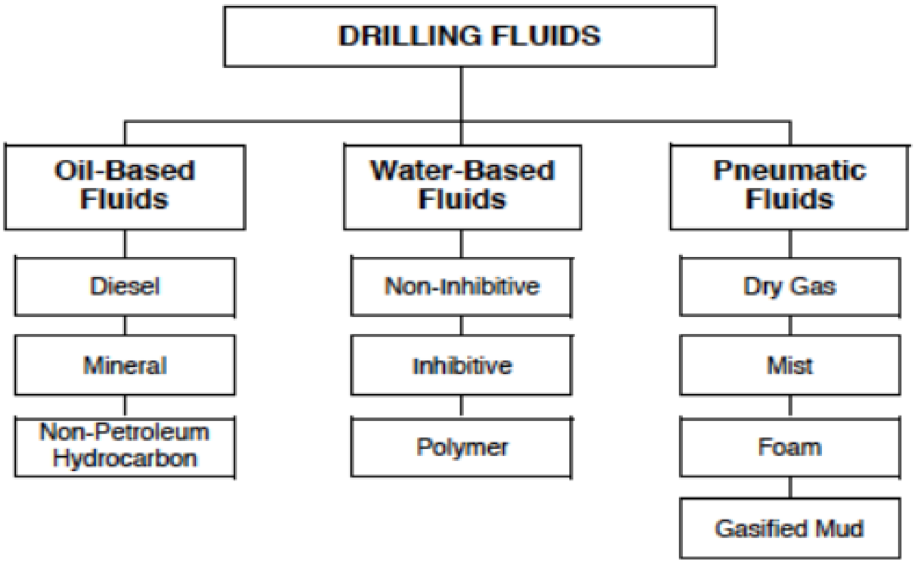

Figure 1: Illustrates the Classification of drilling fluids [4].

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To properly, safely, and efficiently drill a well, a drilling fluid should perform a variety of tasks. According to wellbore requirements, rig capabilities, and environmental considerations, drilling fluid composition varies. Engineers create drilling fluids to optimise drilling parameters including penetration rate and whole cleaning, regulate subsurface pressures, reduce formation damage, reduce the chance of lost circulation, limit borehole erosion, and control subsurface pressures. Drilling fluid systems also must assist in managing entire cleaning and stability issues unique to these wells since a significant portion of current wellbores are severely deviated. Since their introduction into the rotary drilling process between the years of 1887 and 1901, drilling fluids have experienced tremendous progress in a variety of areas to keep up with the evolution of drilling technology [5], [6]. Such progress clearly increased the variety of drilling fluids that were accessible, necessitating the ongoing updating of the criteria for classifying drilling fluids. New criteria, in in addition to the traditional functions of drilling fluid, have been added with the time that has passed and increased awareness of health, safety, and the environment, as well as worries about economics. The following are some of the other specifications which the drilling fluids must meet: not to harm the drilling crew, not to harm the environment or offend anybody, Should not involve using complicated or costly techniques to finish the drilled hole, really shouldn't obstruct the fluid-bearing formation's regular production, and not to corrode or make drilling equipment wear out too quickly.

Drilling Fluid Functions

The drilling mud must accomplish the following fundamental tasks: to maintain hydrostatic pressure that is larger than the pressure gradient in order to regulate subsurface pressures. This attribute is influenced by the weight of the mud, which would in turn is influenced by the density of the continuous phase and the kind of solids that were added to the fluid that made up the mud. To take out the drilling waste from the hole. Cuttings removal is influenced by "gels," which serve to keep the cuttings suspended while the mud is static, and by the viscous characteristics known as "Yield Point," which affect the carrying capacity of a flowing mud. Mud flow rate is another important factor in cleaning the excavation. To lubricate and cool the drill pipe and bit. The drilling fluid cools and lubricates the bit as it travels through into and around the revolving drilling assembly. The drilling fluid receives thermal energy transfer and then transports the heat towards the surface.

Heat exchangers might well be employed at the surface for cool the drilling mud in particularly hot drilling settings. To stop the whole’s walls from collapsing. This purpose is accomplished by the wellbore's walls forming a stable mud cake, similar to plastering a room's walls to prevent flaking. After circulation is shut off, to suspend the cuts and weighing materials (gelation). Gels with low shear viscosity characteristics give this feature. Wellbore stability is maintained by using drilling mud. Controlling clays, reducing hydraulic erosion, and managing density are the fundamental elements of wellbore stability. By slightly over swinging the mud column's weight against the formation's pore pressure, density was maintained. By balancing overall geometry against cleaning needs, fluid carrying capacity, and annular flow velocity, engineers reduce hydraulic erosion. The management of clay is a difficult procedure. In the presence of water, the certain clays in the some formations expand, while others scatter. The drilling fluid's qualities may be changed in order to some extent regulate these effects. Regardless of the method used, reducing the fluid's impact on the formation aids in regulating the borehole, maintaining the cuttings' integrity, and producing cleaner, more readily maintained drilling fluid. To reduce the swelling strains brought by the mud's interaction with both the shale formations. This reaction may result in extensive erosion or caving, which would make the wellbore unstable. The "inhibition" property of the drilling mud reduces wellbore instability.

Bibliography

[1] L. Jassim and R. Yunus, “Simulation model of nano and conventional drilling fluids performance in horizontal well,” *Adv. Appl. Fluid Mech.*, 2017, doi: 10.17654/FM020020249.

[2] M. Ali *et al.*, “Nanomaterial-based drilling fluids for exploitation of unconventional reservoirs: A review,” *Energies*. 2020. doi: 10.3390/en13133417.

[3] M. Al-Yasiri and D. Wen, “Gr-Al2O3 Nanoparticles-Based Multifunctional Drilling Fluid,” *Ind. Eng. Chem. Res.*, 2019, doi: 10.1021/acs.iecr.9b00896.

[4] T. Gupta and E. Studies, “SUMMER INTERNSHIP PROGRAM – 2021 DRILLING FLUID SYSTEM Under the Guidance of,” no. October, 2021.

[5] M. A. A. Alvi, M. Belayneh, S. Bandyopadhyay, and M. W. Minde, “Effect of iron oxide nanoparticles on the properties of water-based drilling fluids,” *Energies*, 2020, doi: 10.3390/en13246718.

[6] X. Zhu, K. Shen, and B. Li, “Investigation: Cutting transport mechanism in inclined well section under pulsed drilling fluid action,” *Energies*, 2021, doi: 10.3390/en14082141.

CHAPTER - 9

CLASSIFICATION OF NON DAMAGING DRILLING FLUID

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Non Damaging Drilling Fluid (NDDF) is a technique for boosting oil output by limiting drilling-related formation damage. To prevent formation damage and preserve the integrity of the pay zone or reservoirs, the NDDF is a polymer mud system that is devoid of clay and barite. Long-chain, high-molecular-weight polymers are included into the systems whether it's to coat the shales for suppression or even to encapsulate drill materials for prevent dispersion, as well as to improve viscosity and decrease fluid loss. The pay zone in Figure 1 is immediately sealed off by using a wide variety of particle sizes that, upon dehydration, fit together create a highly compacted, very low permeability mud cake upon that surface of the rocks. In order to minimize formation damage, reduce total well expenses, and maximize output while still adhering to HSE rules, the planned or ideal NDDF should be created. Need to keep all required drilling fluid qualities include materials of certain sizes to fill up all exposed pore holes. Deposit a non-damaging filter cake that can be withdrawn quickly and easily after initial creation and/or treatment with light reactants or oxidizers [1]–[3].

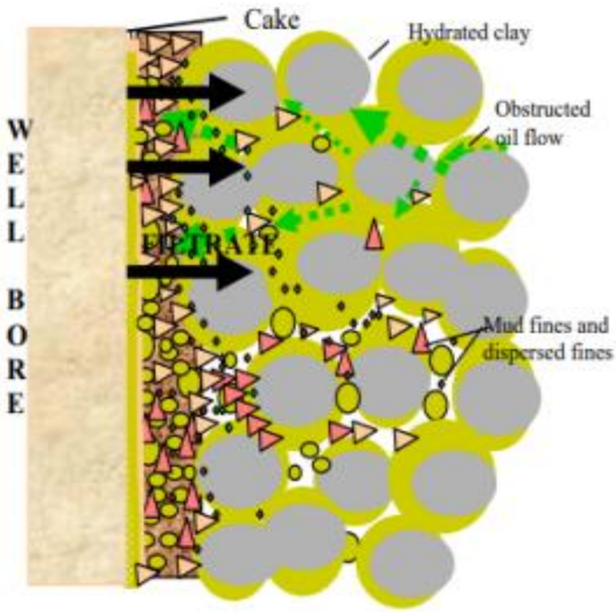

Figure 1: illustrates the pay zone damage by dispersed non-inhibitive muds [4]**.**

The productivity of an oil well relies on the management of formation damage practised during the drilling of the well for a certain geology, well geometry, and production mode. Oil production is anticipated to be higher in a formation with less damage. Although all productive reservoirs were vulnerable to formation degradation, sandstone is much more sensitive to the impact of well bore fluids that lime stone, which produces via a fracture process (Figure 2). Damage to the target zone due to improper drilling fluid composition and parameters could affect the oil output from a newly drilled well [5], [6]. These are some brief summaries of the primary processes of formation damage attributable to drilling fluid. Formation obstruction caused by clay-like particles in drilling fluid. Drilled-cutting formation plugs (drilled fines

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dispersed in drilling fluid). Particles of polymers clog formation. Filtrate hydration of the clay shell that surrounds the pay zone particles. Fine particles that may block the formation pores are also produced as a result of the clay envelope's consequential dispersion. Filtrate alters wettability. Mud invasion across the pay zone as a result of induced reduced circulation In order to prevent the aforementioned formation damage processes, an ideal productive drilling fluid really should not cause scales as a result of a chemical interaction between the formation fluids with mud filtrate. No use of compositional fine solids that cannot degrade, such as clay, barite, etc. Minimum fine solids in drilling. Effective barrier against polymer particles entering the pay zone. No dispersant should be used in the mud, and inhibitive filtrate should not enlarge the clay envelop surrounding pay zone particles. Less loss during filtering. For avoiding total mud invasion during excursions and gel break circulations, the lowest feasible progressive gelation should be used. Filtrate and formation fluid do not chemically react to produce an insoluble precipitate.

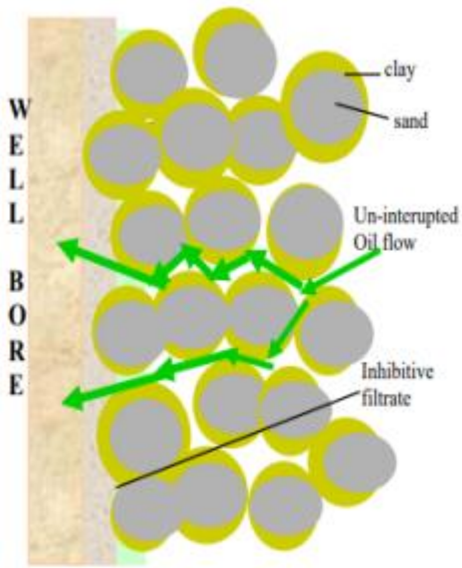

Figure 2: Illustrates the intact pay zone with NDRF.

NDDF advantage over conventional drilling fluid

NDDF offers various benefits over traditional scattered muds and reduces formation damage. Conventional muds' fine particles penetrate deeply into the formation & obstruct the flow of oil between reservoirs to well. NDDF is devoid of fine solids (clay). Thixotrophy, the most important characteristic of drilling fluid, is given by the biodegradable additive XC polymer. The clay encircling the pay zone's sand particles expands due to mud filtrate. This prevents the flow of oil. Clay swelling is prevented by the saline inhibitive filtrate produced by the NDDF. Calcium carbonate ($CaCO_3$) particles in NDDF that have been carefully chosen for size span the pore mouths on the forming surface to produce an external filter cake. In comparison to an interior filter cake within the forming matrix, an exterior filter cake is considerably simpler to remove by drawing down. Additionally, NDDF is given a greater specific gravity using calcium carbonate (instead of barites used in conventional muds). Since calcium carbonate is soluble in acid, it may be eliminated later. Fine clay particles are produced by the dispersant's presence and travel through the formation matrix to clog the pores. No blockage is caused by dispersion-generated particles since NDDF doesn't include any dispersant.

Bibliography

[1] S. Medhi, S. Chowdhury, N. Bhatt, D. K. Gupta, S. Rana, and J. S. Sangwai, “Analysis

of high performing graphene oxide nanosheets based non-damaging drilling fluids through rheological measurements and CFD studies," *Powder Technol.*, 2021, doi: 10.1016/j.powtec.2020.08.053.

[2] P. Talukdar and S. B. Gogoi, "A Study on the Role of Pre-Gelatinized Starch (PGS) in the Non Damaging Drilling Fluid (NDDF) for the Tipam Sand of Geleki Oilfield of Upper Assam Basin," *Int. J. Appl. Sci. Biotechnol.*, 2015, doi: 10.3126/ijasbt.v3i2.12552.

[3] E. Yalman, G. Federer-Kovacs, T. Depci, H. Al Khalaf, V. Aylikci, and M. G. Aydin, "Development of novel inhibitive water-based drilling muds for oil and gas field applications," *J. Pet. Sci. Eng.*, 2022, doi: 10.1016/j.petrol.2021.109907.

[4] T. Gupta and E. Studies, "Summer Internship Program – 2021 Drilling Fluid System Under the Guidance of," no. October, 2021.

[5] S. Medhi, D. K. Gupta, and J. S. Sangwai, "Impact of zinc oxide nanoparticles on the rheological and fluid-loss properties, and the hydraulic performance of non-damaging drilling fluid," *J. Nat. Gas Sci. Eng.*, 2021, doi: 10.1016/j.jngse.2021.103834.

[6] I. M. Alcheikh and B. Ghosh, "A Comprehensive Review on the Advancement of Non-damaging Drilling Fluids," *Int. J. Petrochemistry Res.*, 2017, doi: 10.18689/ijpr-1000111.

CHAPTER - 10

DESIGNING OF MUD

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Mud enters the formation as a result of the overbalance pressure, which might harm the formation. Plugging the pores with invading particles that were previously suspended throughout the drilling fluids will decrease the permeability of the rock. Mud filtrate may interact with formation elements to mobilize in-situ particles and then re-deposit them, to swell pay-zone clay, to change the wettability of reservoir rock, to generate emulsions that reduce permeability, and many other things. Less harm is done, but more hydrocarbon is produced. Therefore, in order to minimize formation damage, it is crucial to keep the following in mind while developing a successful mud: Reduce fluid loss [1]–[3]. Dispersant and non-biodegradable fine particles, such as bentonite, barite, etc., shouldn't be used in the mud. Reduce the amount of fine particles in the mud from drilling. Produce an inhibitive filtrate that won't enlarge the clay envelop throughout the formation particles or interact with the fracturing fluid to produce the insoluble precipitate seen in Figure 1.

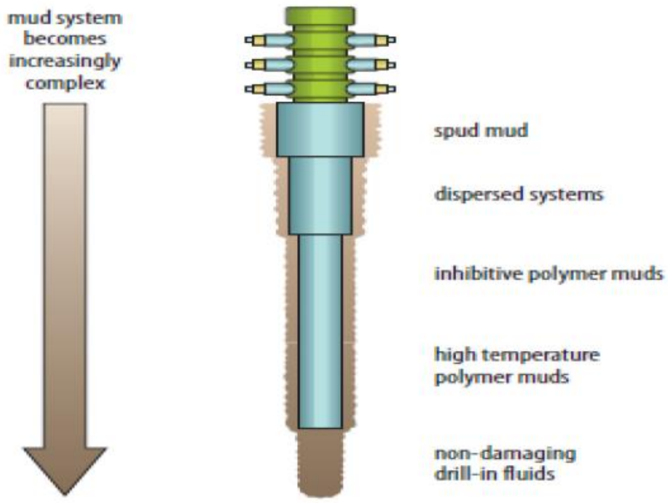

Figure 1: illustrates the Drilling Fluid Composition Requirements.

One of the guiding principles for drilling vertical wells is to minimise reservoir formation damage induced by drilling (pay zone). The application of this idea to horizontal and greatly deviated wells has additionally been made. Any well should operate to the maximum extent possible for the formation that penetrates and maintain stability throughout the course of its lifetime. One of the most crucial steps in the drilling process is drilling the pay zone, therefore drilling fluid that would be needed or sufficient for drilling the remainder of the well could not be suitable in the pay zone. Preventing the loss of a drilling fluid filtrate and ensuring that the filtration that is lost won't react with both the formation to lower permeability are the two most crucial features of a drilling fluid from the perspective of formation damage [4], [5]. Ascertaining and quantifying the intricate, frequently interdependent electrostatic interactions and chemical changes that take place downhole between both the reservoir rock fluid but also minerals as well as the drill-in / completion fluids utilised is one of the key factors in maximizing wellbore connectivity and maintaining the organic reservoir rock permeability and water sorption. Drill-in fluids are drilling fluids that are utilised when drilling operations are

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about to enter pay zones or penetrate horizontal drilling. They allow wells to be drilled into reservoir formations with the least amount of damage possible, maximizing output.

Current Development in Drilling Fluids

Diesel oil is the most extensively utilised oil component in both water-in-oil emulsion muds and oil-in-water muds, however several grades of petroleum-based oils are employed to satisfy the range of demands in drilling technique. Diesel oil is utilised to minimize stick pipe issues, boost drilling lubrication, and improve rheological qualities and limit filtering losses. Their stability under HTHP circumstances, which diminishes with increasing temperature as the frequency of collisions between both the droplets grows, is one of the main issues with practically all varieties of drilling fluids having an oleic phase. The petroleum industry has become interested in the use of paraffinic-based minerals as drilling fluid substitutes for diesel oil. Although mineral oil-based drilling fluid systems offer similar features to diesel oil-based emulsion drilling fluids, they also have major drawbacks. It should be mentioned that drilling fluids based on mineral oil are less harmful than those based on diesel oil, according to the results of laboratory toxicity tests. Additionally, tests have shown that mineral oil-based drilling fluids have poorer oil retention qualities than diesel-based drilling mud. Low viscosity drilling fluids are mineral oil-based muds with an invert emulsion basis. In their investigation, palm oil mixed groundnut oil were combined to generate an environmentally beneficial oil-based mud.

They discovered that groundnut and palm oil-based drilling fluids had better rheology than diesel-based oil mud, indicating that when these oil-based muds palm oil and peanuts oil-based muds were dumped on a corn field, they had no negative effects on the plants. With the aid of an acid-based chemical switch, the reversible inversion emulsion drilling fluids are a form of emulsion-based drilling fluid that can be reversibly changed from water-in-oil (W/O) emulsion to oil-in-water (O/W) emulsion and back to W/O emulsion. Utilizing emulsion-based drilling fluids again for best drilling performance is a cutting-edge strategy. Reversible invert emulsion technologies are straightforward and simple to use. Since the surfactant was non-ionic and not protonated, brines mostly have no effect on it. The surfactant's non-ionic nature allows it to compact with some other oil-based drilling fluid additions and is not dependent on the kind of base oil used in the continuous phase. However, these surfactants take on a nucleophile form (regular emulsifiers) and create an oil-in-water emulsion in the addition of water-soluble acids. Any variety of inorganic or organic solutions that are water soluble may be used to protonate the surfactant. The drill cuttings' oil-covered surfaces may be changed to water-covered surfaces, which is better for the environment. Compared to operations without inversion emulsion muds, cleaning the filter cake is simpler.

Reversible invert emulsion drilling fluid

A drilling fluid that may easily and reversibly change from an oil-in-water emulsion to a water-in-oil emulsion is known as a reversible inversion emulsion drilling fluid. Although maintaining all the benefits of water-based drilling fluids, it displays the greatest drilling performance, as is common for oil-based muds. With the exception of the emulsifiers, the formulation of reversible rheological properties drilling fluid systems is comparable to oil-based drilling fluid systems on the basis of both composition and performance. The reversible inversion emulsion fluid's performance qualities are significantly influenced by the emulsifiers employed in it. In the presence of alkaline elements (such as lime), the surfactants utilised in this reversible system generate a highly stable invert emulsion; but, in the absence of water-soluble acids, those surfactants transform into direct emulsifiers and form indirect emulsions. By adding acid, this same invert emulsion created with the surfactant may be transformed into a direct emulsion, and by treating with base, it can be transformed back into an invert emulsion.

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Bibliography

[1] B. A. Hamad *et al.*, "A Novel Amphoteric Polymer as a Rheology Enhancer and Fluid-Loss Control Agent for Water-Based Drilling Muds at Elevated Temperatures," *ACS Omega*, 2020, doi: 10.1021/acsomega.9b03774.

[2] B. Bloys *et al.*, "Designing and managing drilling fluid," *Oilf. Rev.*, 1994.

[3] L. Salehnezhad, A. Heydari, and M. Fattahi, "Experimental investigation and rheological behaviors of water-based drilling mud contained starch-ZnO nanofluids through response surface methodology," *J. Mol. Liq.*, 2019, doi: 10.1016/j.molliq.2018.11.142.

[4] A. M. Salem Ragab, "Mitigation of formation damage by designing a novel nanoparticles mud," *Oil Gas Eur. Mag.*, 2014.

[5] M. A. Issa and F. A. Hadi, "Estimation of mechanical rock properties from laboratory and wireline measurements for sandstone reservoirs," *Iraqi Geol. J.*, 2021, doi: 10.46717/igj.54.2D.10Ms-2021-10-29.

CHAPTER - 11

POLYANIONIC CELLULOSE POLYMER (PAC)

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PAC High purity polyanionic cellulose is utilised as the primary fluid loss reduction in water-based drilling fluids. Drilling fluid additive polyanionic cellulose (PAC) is commonly utilised. Its molecular makeup is comparable to that of carboxymethyl cellulose (CMC). In aspects of filtration reduction, anti-salt, anti-collapse, but also resistance to high temperatures it is regarded as superior than CMC. It works at temperatures as high as 150 °C. Because it often has a greater level of carboxymethyl substitution and occasionally contains less residual sodium chloride, PAC is regarded as a premium product. To help with a number of processes, including the cooling and lubrication of the mud bit, the suspension of formation cuttings, the facilitation of surface transportation, as well as the control of formation pressure all through the oil well, PAC polyanionic cellulose has been added to drilling fluids as well as other chemical mixtures. By rendering the drilling fluid stiffer, the use of PAC helps avoid any hazardous conditions throughout the production process, such as well obstructions or bore collapses. The quantity of water required to enter the productive zone may be decreased because to its low water loss characteristics. PAC may be used to alter the PH levels of a combination as well as the viscosity degrees of the mud. There are two primary PAC versions available [1]–[3].

Low Viscosity Polyanionic Cellulose (PAC-LV)

It possesses excellent salt, calcium, and magnesium resistance, significant water solubility, and the capacity to reduce fluid loss. Features include: Polyanionic Cellulose has a high transparency and homogeneous replacement that allows it to regulate viscosity and reduce fluid loss. For the water-base muddy of fresh water, seawater, particularly saturated salt water, polyanionic cellulose is suitable. The prepared fluid is more capable of rejecting fluid loss and has a greater temperature resistance. Because the manufactured fluid has improved rheological characteristics and can stop clay and shale from dispersing and swelling in high salt environments, Polyanionic Cellulose may be used to manage shaft wall pollution [4]–[6]. Polyanionic Cellulose aids in maintaining the strength of fragile soil and guards against shaft wall collapse. Whenever the drill passes through rock walls, polyanionic cellulose may reduce the amount of particles that collect in the fluid. By reducing the amount of turbulence throughout the drilling pipe, polyanionic cellulose allows the reverse-flow mechanism to maintain the lowest possible stress loss. The mud's ability to boost yield and lower filter loss is enabled by polyanionic cellulose. Using polyanionic cellulose, mud foam may be kept stable.

High Viscosity Polyanionic Cellulose (PAC-HV)

By trying to form a relatively thick surface of solvent absorption on the drilling fluid particle surface, PAC HV can increase the stability of the program's coagulation, decrease the electrostatic attraction respectively particles, increase the surface charge of particulate by absorbing fine clay particles, and increase the penetrability of filter cakes by improving the viscosity and ability of filtrate to plug the holes. All water-based drilling fluids, including saturated saltwater drilling fluids, may readily disseminate PAC HV. PAC HV may significantly decrease filter loss and filter cake thicknesses in low-solid and solid-free drilling fluids and exhibits strong inhibitory activity on shale hydration. It is a high-quality cellulose derivative that is water soluble. It comes in the form of an odorless, tasteless, non-toxic, and non-fermented free-flowing powder. It also has outstanding thermal stability as well as a high salt resistance. It may be dissolved in water to create a thick liquid and is often used in water-based drilling fluid to increase viscosity and reduce fluid loss. Applications of PAC-HV include filtration control, viscosity control, and shale inhibition. These applications are often employed in water-base drilling fluid. It can control filtration in freshwater or saltwater-based drilling fluids, encourage borehole stability in water-sensitive formations, minimize rotational torque as well as circulating pressure, enhance hole cleaning as well as core recovery, stiffen foam to continue improving cuttings transport in air/foam oil exploration and reduce air prerequisites, increase hole velocity and borehole annulus pressure throughout air/foam drilling, and more.

Pre-Gelatinized Starch

Pregelatinized starch is often used as an ingredient to drilling mud to increase drilling mud viscosity and decrease fluid loss through sealing the borehole walls. This prevents seepage of soil filtrates entering wells. Pregelatinized starch increases solids removal & hydraulic efficiency while allowing drills to move more freely, reduce fluid loss, and maintain a stable temperature. It is a naturally occurring non-ionic polymer that works very well in all types of water, including fresh, marine, saturation salt water, calcium chloride, potassium chloride, and virtually any other brine-based systems. For resistance against bacterial but also enzymatic degradation, high-quality biocide has been added. Pre-Gelatinized Starch (PGS), an environmentally acceptable non-ionic polysaccharide, has been included in the NDDF to manage mud cake thickness, filtration, and particle invasion by making drilling fluids viscous and sealing this same borehole walls with its long monosaccharide chains. PGS performs well as the NDDF's fluid loss control agent, and it also plays a little part in regulating the mud's rheology. However, the PGS is restricted to shallow depths and low temperatures. As a fluid loss reduction and coating agent for fresh and salt water, Poly Anionic Cellulose (PAC) is also utilised in the NDDF as a component that withstands high temperatures and biodegradation. It also performs admirably as a rheology and fluid loss control reagent in NDDF, which also plays a limited function in regulating the thickness of the mud cake.

XC POLYMER

In order to provide rheology for excellent lifting capacity & ROP and to encapsulate drill materials to avoid dispersion, the non-degradable Bentonite (clays) is replaced with the biopolymer XC-Polymer with NDDF. It functions as a coating agent with inhibition as well as a fluid loss reduction. A high molecular weight polysaccharide called XC-Polymer is created by fermenting carbohydrates with Xanthomonas Campestris. Regardless of the absence of inorganic colloids, this high grade viscosifier exhibits remarkable shear thinning qualities and acceptable suspension characteristics. High penetration rates, borehole cleaning, including pay zone protection are all made possible by this. The rheological characteristics of drilling fluid improve when XC-Polymer concentration rises. Even as concentration of XC-Polymer rises, the filter cake's thickness, porosity, and permeability all slightly decrease as well. It biodegrades rapidly. XC-Polymer is therefore employed in NDDF as a replacement for the non-degradable clays (e.g., Bentonite). As the rheology agent in various in NDDF, XC-Polymer performs well. It also plays a modest role in regulating the mud's fluid loss. Commonly known as XC polymer, this polysaccharide is released by the bacterium Xanthomonas campestris. Due to the flat velocity profile it creates in annular flow, which is necessary for effective cuts lifting in lower density muds, XC in water muds gives non-Newtonian mud rheology, which would be extremely desired. The anionic XC polymer is

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tolerable to salinity and has a passable tolerance to hardness ions. The amount of lingering bacterium debris as well as the ease at which it disperses throughout water may vary with XC, a finely ground substance. With respect to water-phase components, temperature tolerance varies, but it begins to deteriorate about 200 to 250. (121 degC). The XC polymer is prone to bacterial assault and does not withstand extreme pH or hardness.

Bibliography

[1] M. G. Temraz and I. Hassanien, "Mineralogy and rheological properties of some Egyptian bentonite for drilling fluids," *J. Nat. Gas Sci. Eng.*, 2016, doi: 10.1016/j.jngse.2016.03.072.

[2] C. M. Silva, A. J. Ribeiro, D. Ferreira, and F. Veiga, "Insulin encapsulation in reinforced alginate microspheres prepared by internal gelation," *Eur. J. Pharm. Sci.*, 2006, doi: 10.1016/j.ejps.2006.06.008.

[3] M. V. Kok and T. Alikaya, "Effect of polymers on the rheological properties of KCl/polymer type drilling fluids," *Energy Sources*, 2005, doi: 10.1080/00908310490441809.

[4] S. Davoodi, A. Ramazani S.A., S. Jamshidi, and A. Fellah Jahromi, "A novel field applicable mud formula with enhanced fluid loss properties in High Pressure-High Temperature well condition containing pistachio shell powder," *J. Pet. Sci. Eng.*, 2018, doi: 10.1016/j.petrol.2017.12.059.

[5] L. V. Amorim, M. I. R. Barbosa, H. de L. Lira, and H. C. Ferreira, "Influence of ionic strength on the viscosities and water loss of bentonite suspensions containing polymers," *Mater. Res.*, 2007, doi: 10.1590/S1516-14392007000100012.

[6] H. Mahmoud, M. Alhajabdalla, M. S. Nasser, I. A. Hussein, R. Ahmed, and H. Karami, "Settling behavior of fine cuttings in fiber-containing polyanionic fluids for drilling and hole cleaning application," *J. Pet. Sci. Eng.*, 2021, doi: 10.1016/j.petrol.2020.108337.

CHAPTER - 12

XANTHAN GUM

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Xanthan gum is a polysaccharide created through the fermentation of simple sugars by a bacteria called Xanthomonas campestris. It's a member of a family of polymers called hydrocolloids, which are both water-soluble and hydrophilic, meaning its molecules are attracted to water. Having an attraction to water is an essential characteristic of xanthan gum, as water is the base carrier fluid in drilling muds. Operators use xanthan gum as a thickening agent in drilling muds to increase the mud's viscosity. When mixed into water, xanthan gum swells, and the mixture takes on a gel-like consistency that has proven to be an excellent carrier of drill cuttings. Even when the flow of drilling mud stops, the viscous mixture helps keep cuttings trapped in suspension instead of allowing them to fall down the drilling pipe due to gravity. Xanthan gum has been used extensively as a viscosifier in the oil field for drilling, drill-in and completion fluids due to its unique rheological properties. In this paper we explore the rheological properties of xanthan-based fluids in Berea sandstone rocks and how these properties can be used to control fluid loss. Xanthan gum, a high-molecular weight biopolymer, provides versatile rheology control in a wide range of brines, drilling and fracturing fluids [1]–[3].

Xanthan gum is regarded as non-hazardous and is appropriate for usage in regions and applications that are sensitive to the environment. Cargill provides xanthan gum solutions that mix well in water at low shear rates without forming lumps or "fisheyes," which are common with uncoated polymers and reduce usability. Xanthan gum is an effective rheological control for a variety of water-based drilling, completion, including work-over fluids in oilfield applications. During drilling and oilfield applications, high viscosity with low concentrations and effective solids transport under high viscosity/low shear circumstances have various advantages, including reduced pumping friction throughout calcareous, freshwater, and saltwater soils. maximum drill bit insertion depth Accelerated drilling speeds with low viscosity under high shear conditions Reduced accumulation of solids in drilling fluids Managing excessive quantities of gravel fluids used in hole-cleaning are stabilized loss reduction in the oil formation decreased maintenance costs overall cost of operating is comparable to reduction pigment in stabilizing suspension decreases suspension duration and has thixotropic qualities prevents coalescence during application and storage enables the stability of microorganisms in water-based compositions.

Hollow Glass Spheres (HGS)

The drilling industry has traditionally found it difficult to drill in low-pressure reservoirs. Poor pressure, low permeability, and depleted zones were difficult to drill because to technical difficulties and increased drilling costs. Due to the drilling fluids' higher density than water, many drilling techniques employ water-based mud into pressure-depleted reservoirs that are vulnerable to significant overbalance pressure. Because of this, the need for lightweight drilling fluids arises. The drilling fluid's primary job is to provide hydrostatic pressure to counteract formation pressure. Dependent on the formation that was drilled, having higher hydrostatic pressure than just the formation pressure might be quite problematic. Circulation loss would be the issue that is most anticipated [4]–[6]. Mud costs have always been greater when

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circulation is lost. Additionally, it causes issues like poorly done cement work, clogged pipes, and unstable wellbore. In addition to these technical and financial problems, it might lead to a loss of well control and possibly blowouts.

Lower density fluids are necessary for drilling low-pressure reservoirs having limited permeability's and depleted wells. Mud densities that exceed given limitations may fracture the formation, result in partial or complete losses of drilling fluid, increase drilling costs owing to longer drilling times, and even result in formation damage. For make the drilling fluid lighter and less dense, hollow glass spheres were introduced to the drilling fluid. The substance is almost insoluble in either water or oil, stable, and incompressible. These really are unicellular hollow spheres made of soda-lime-borosilicate glass, which resembles white Pyrex. They can withstand high pressure under downhole environments because to their excellent strength to weight ratio. The density of HGS varies between 0.38g/cc and 0.42g/cc dependent on the particle size variations between 15m and 135m and pressure resistance. 600°C is the softening temperature. Because of the increasing need for "hydrostatic pressure control" with high-performance low-density fluids, the practice of employing HGS to lower the density has assumed greater significance. HGS is simple to combine with any kind of drilling mud by calculating the volume by 50%. A suitable substitute with low weight drill-in fluids is water-based with HGS due to economic and environmental concerns.

Drilling Blind

Drilling may cause circulation losses in certain crucial places that are so severe that traditional treatments to repair the loss zone are rendered useless. Losses are so great that before running casing, drilling blind (with no returns) is employed to penetrate the loss zone and enter a competent formation. With this technique, no returns are fastened at the surface and a sacrificial, cheap, and straightforward drilling fluid, including such water, is pushed down the drilling process to cool the bit and transport the cuttings into the loss zone. This is a possible concern for conditions of overall management and stability. The addition of a floating mud cover while drilling blind is a significant modification. An ongoing viscous slug of water-based gel mud is pumped into the annulus to create the mud cap. In this instance, the hydrostatic pressure of a drilling mud throughout the annulus controls the well. Another similar drilling technique is known as "flow drilling," and it entails drilling underneath the pore pressure while allowing formation fluids too flow from the annulus by pushing water or oil down the drill pipe. These three procedures—mud cap, flow drilling, and drilling blind—have been improved, and certain dangers have been eliminated, for instance, by MPD or UBD approaches.

Managed Pressure Drilling

In MPD, the annular pressure profile was controlled throughout the wellbore throughout the drilling operation. To minimize the overbalance pressure and avoid instability, the corresponding mud weight needed is calculated and applied. This minimizes the influence on the formation and increases stability. According to the needed equivalent circulation density, MPD may be used to apply methods like "mud caps" and various drilling fluid types, such as foams, aerated fluids, and water- or oil-based drilling fluids (ECD). By focusing on the utilization of closed and pressurized systems, MPD systems therefore provide alternative to traditional drilling techniques (with flow lines exposed to the atmosphere). By enhancing process control, raising general rig crew, facility, and environment safety, and enabling greater data resolution collection, this results in a decrease in drilling issues.

Underbalanced Drilling

With UBD, it is possible to manage significant fluid losses and other issues that are common with traditional overbalanced drilling. In this situation, it is deliberate that the hydrostatic head

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of a drilling fluid be less than the pore pressure of a formation being drilled. There might be an inflow of formation fluids as a consequence, which would need to be cycled from the wellbore and managed at the surface. The hydrostatic head may well be artificially increased or it may naturally be lower than the formation pressure. There is no need to change the well fluid further if the hydrostatic head is already lower than the formation pressure. A lighter ECD will be needed, however, if the hydrostatic head was higher than the formation pressure. Depending on the needed ECD, a gas, mist, foamy, or gasified fluid system is often used to obtain a lower circulation density. In these devices, the gas may be introduced to the fluid system to produce or induce the unbalanced situation, and it can be natural gas, ammonia, or air.

Bibliography

[1] Z. Lufeng, Z. Fujian, Z. Shicheng, L. zhun, W. Jin, and W. Yuechun, “Evaluation of permeability damage caused by drilling and fracturing fluids in tight low permeability sandstone reservoirs,” *J. Pet. Sci. Eng.*, 2019, doi: 10.1016/j.petrol.2019.01.031.

[2] S. Saha, U. D. Hemraz, and Y. Boluk, “The Effects of High Pressure and High Temperature in Semidilute Aqueous Cellulose Nanocrystal Suspensions,” *Biomacromolecules*, 2020, doi: 10.1021/acs.biomac.9b01130.

[3] Y. Kang, Q. Chen, L. You, C. Lin, and Q. Cheng, “Laboratory studies of shale fracturing behaviors with rock-drilling fluid interactions,” *Zhongguo Shiyou Daxue Xuebao (Ziran Kexue Ban)/Journal China Univ. Pet. (Edition Nat. Sci.*, 2016, doi: 10.3969/j.issn.1673-5005.2016.04.010.

[4] T. Ç. Arı and S. Akın, “An Experimental Study on Usage of Hollow Glass Spheres (HGS) for Reducing Mud Density in Geothermal Drilling,” *World Geoterm. Congr. 2015*, 2015.

[5] W. Zhang, X. Zhangsun, and Y. Tao, “Photocatalytic degradation of Red 2G on the suspended TiO2-hollow glass sphere,” *React. Kinet. Mech. Catal.*, 2021, doi: 10.1007/s11144-021-02078-6.

[6] A. Konbul, E. M. Ozbayoglu, and C. Mata, “Survival of hollow glass microspheres in drilling fluids applications – Effect of drill bit/formation contact,” *J. Pet. Sci. Eng.*, 2020, doi: 10.1016/j.petrol.2020.106966.

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