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SIDERITE AS A WEIGHTING MATERIAL IN DRILLING MUD

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SIDERITE AS A WEIGHTING MATERIAL IN DRILLING MUD

Abstract
Successful petroleum drilling largely depends on the type and quality of mud used in the process. There exist many types of muds, which differ in use and composition. Certain muds are composed of materials that can cause damage to the formation and the bottom-hole. This has resulted in the search for alternatives mud additives or addition of new materials to minimize the damage of the formation and enhance the stability of the wellbore. Several bodies of literature exist that research different sources of mud functions and additives, also their effect on the drilling process, the production zone and the environment. Density is one of the main properties of drilling mud because it is the responsible in controlling the formations pressure. So, many weighting agents exist to increase the density of drilling mud. Barite ($BaSO_4$) has a specific gravity of 4.2–4.5 and hardness 2.5-3.5. It has been the most common weight material used in drilling fluids, it is preferred to other weighting materials because of its low cost and high purity but its main disadvantage that its composed of large amount of insoluble acid which damage the formation due to the invasion of the solids into the production zone. A new weighting agent that can be used instead of barite would be a new innovation in the oil field. Siderite ($FeCO_3$) is a weighting material which has a specific gravity of 3.9 and a hardness of 3.5 and makes the mud weighted up to 20 lb/gal. It is specified by a high acid solubility which didn't cause damage to the formation compared to barite. So, it can be used as an alternative weighting material in both oil and water muds due to its high specific gravity and high acid solubility.

Keywords
Drilling mud, density, weighting material, barite, siderite

1. INTRODUCTION

Petroleum drilling is one of the most important steps in the oil field. The success or failure of this process largely depended on the drilling mud used, also the casing setting depth being selected is the next most critical point in order to achieve a successful drilling campaign by using the appropriate drilling fluid. So, the type and composition of the drilling mud are a vital element of the drilling system to perform several functions in the drilling process; such as controlling the formation pressure, removing the drill cutting from the bottom hole and transporting them to the surface, lubricating and cooling the drill string and bit, stabilizing the wellbore and making a thin and low permeability filter cake across formations (Nguyen, 1996).

Most of the problems that occur during drilling are related to the type and the composition of the drilling mud, so the appropriate selection of drilling mud (type and composition) lead to the success of the drilling process (Hossain, 2018).

There are three types of drilling fluids used in oil and gas industry which differ by their use and composition are: oil-based muds, water-based muds and the gas mud. The mud properties controlling the technical key functions are: Density, Viscosity, Rheology -including Plastic viscosity, Yield point, Gel Strength-, Filtration and PH (Caenn et al., 2017).

Weight agents are materials that are used to increase the density of drilling mud by suspended or dissolved in it. Their primary function is to control formation pressure by creating sufficient hydrostatic pressure in the hole (overbalanced drilling) which assure borehole stability, also it reduces the amount of fluid loss in formation by make a filter cake on the borehole walls. Increase in density also results in increasing the penetration rate. Underbalanced drilling which mean the hydrostatic pressure is lower than formation pressure may cause inflow of formation fluid to the wellbore which may result in a kick and eventually a blowout (Bahadory, 2012). In short, drilling fluid density must not be too high to avoid lost circulation which causes formation damage when hydrostatic pressure is higher than the fracture pressure, also to avoid the decreasing in the rate of penetration due to the hold down effect, but at the same time, density must not be too low in order to stay in an overbalance situation to prevent kick and blowout.

Barite ($BaSO_4$) is specified by its inert and insolubility in acid. It occurs as a vein filling in depositional environments, and is deposited through many processes such as hydrothermal, biogenic and evaporation also it occurs in sedimentary rocks especially limestones, in hot spring deposits, and with hematite ore. It is a heavy agent which is transported in fine powder form, this let it to be easily mixed with drilling muds to increase its density and has the ability to increase mud weight between 18.5 and 19 ppg. (Bonel, 2005).

The drilling mud prepared with the weighting agent “barite” has a main drawback which is the acid insolubility. So, the work is involved to find a new weighting material instead of barite specified by its high specific gravity and high acid solubility.

Siderite ($FeCO_3$) is a pure ferrous carbonate which commonly formed in hydrothermal veins associated with galena, barite and others. It formed also in sandstones and shales as diagenetic mineral. It buried at shallow depths. It has higher density than calcium carbonate and highly soluble in formic and hydrochloric acids. So, drilling muds that contain ferrous carbonate did not damage the formation because of its acid solubility (Sample, 1982). Just as other materials that can be used as weighting materials, siderite was being investigated in a literature review to know its potential to be used as a weighting mud in drilling fluid.

2. DRILLING MUDS

2.1 Mud Properties Controlling Technical Key Functions

Simpson (1985) provided a literature-based study on the importance of the drilling mud properties in controlling the technical functions. He emphasized the importance of mud density in balancing the formation pressure and enhancing the stability of the borehole. Simpson (1985) also highlighted the importance of low viscosity and explained how can this low viscosity provides high rate of penetration. He is also in favor of low gel strength which can help in cleaning the bottom of the hole by transporting the drill cutting to the surface. Finally, he explained that high filtrate can minimize chip hold-down and facilitates faster drilling.

2.2 Selection of a Drilling Fluid

Bleier (1990) emphasized that the selection of the appropriate drilling mud is paramount to the success of a drilling process. Many choices are available with different drilling fluid types, different base fluids, different chemical additives and different physical properties. Drilling mud selection depends on numerous factors such as safety, high temperatures and pressures, shale problems, salt problems, environmental considerations and economics as shown in table 1.

Safety issues: The fluid must be able to provide the mud density required to control the well. Speed and ease with which a mud will accept weighting materials can be important in kick situations. Many mud types are uncapable to control well especially when mud weights exceed 15 Ibm/gal. So, polymer muds will need some dispersant and oil muds will need oil/water ratios higher than 50/50.

In deep-water drilling, gas hydrates can overlap mechanically with well-control conditions. Water-based muds especially salt muds are currently the favorable fluids of choice in deep water due to its high salinity which suppresses the hydrate formation.

The safest muds for drilling zones bearing H2S should contain at least 10 Ibm/bbl excess lime plus a sulfide scavenger. Oil and lime drilling muds are the only two mud types that are compatible with this case.

High Temperatures and Pressures: At high downhole temperatures and pressures, fluid loss problems occur for most water-based fluids, but fluid loss are controlled by using oil-based muds. So, oil fluids are a viable at these high temperatures and pressures.

Shale problems: Shale formations can disperse, slough or swell into the hole. Shale swelling are the most common mud-related drilling problem occur around the world. This type of problem is mechanical in nature. Increasing the mud density and the appropriate composition of drilling muds are important to the solution. Theory and experience indicate that asphaltic agents reduce sloughing, long chains polymers reduce dispersion, and dissolved salts reduce swelling.

Laboratory tests showed that water-based muds are unsuccessful in eliminating shale problems due to its high dissolved salts which cause shale swelling. But, oil-based muds eliminate shale problems because they provided adequate mud weight and enough salinity of the aqueous internal phase.

Salt Problems: Salt formations are unique. Salt has little porosity and permeability. It can flow plastically through other geological rock beds under stress with "salt creep" resulting in wellbore size reduction and casing collapse. Salt can also dissolve in water necessitating the salinity of a water-based fluid be kept near or at saturation to avoid or minimize wellbore enlargement that can lead to poor cementing of the casing and deficient zonal isolation.

Environmental considerations: Environmental considerations that related to the process of drilling mud are varied depending primarily on the well location. Many restrictions present to the avoidance of using oil fluid in some locations, salt muds in other locations, chromium-treated muds in still other locations. Drilling-fluid bioassay tests are useful for assessing the toxicity of special additives. So, the search for alternative materials instead of some original toxicity additives continues to be the highest research priority in drilling fluids.

Economics: It includes the cost of the base fluid and the additives, maintenance costs, mud-related disposal costs, type of drilling either underbalanced or overbalanced total costs and for oil muds, buy-back provisions. In some regions, the waste management can represent a high percentage of the total well cost. The most critical part is the volume resulting from dilution. Many companies do not require expensive muds in some wells which make them use some types of low-cost muds such as lignite muds, native-brine starch muds, unweighted-gel freshwater muds and lightly treated lignosulfonate muds, but in some cases the using of synthetic oil based mud becomes more cost effective that makes the industry to use the water based muds.

Table 1: selection of drilling mud (Bleier, 1990)

	Water based mud	Oil based mud
Safety issues	Low	High
High temperature and pressure problem	High	Low
Shale problems	High	Low
Salt problems	High	Low
Environmental consideration	Low	High
Economics (cost)	Low	High

2.3 Functions of Drilling Mud

Moreover, Nguyen (1996) presented in the fifth chapter of his book the ability of drilling mud to perform some major tasks as shown in figure 1 such as (a)exert sufficient hydrostatic pressure against the formation to prevent formation fluids from flowing into the well, (b) carry the drill cuttings which are crushed rock produced by the drill bit to the surface, (c) maintain stability of the borehole walls, (d) cool and lubricate the drill string and bit, (e)protection against corrosion, (f) reducing friction and torque, (g) aiding solids removal and (h) transmission of Data/Hydraulic power.

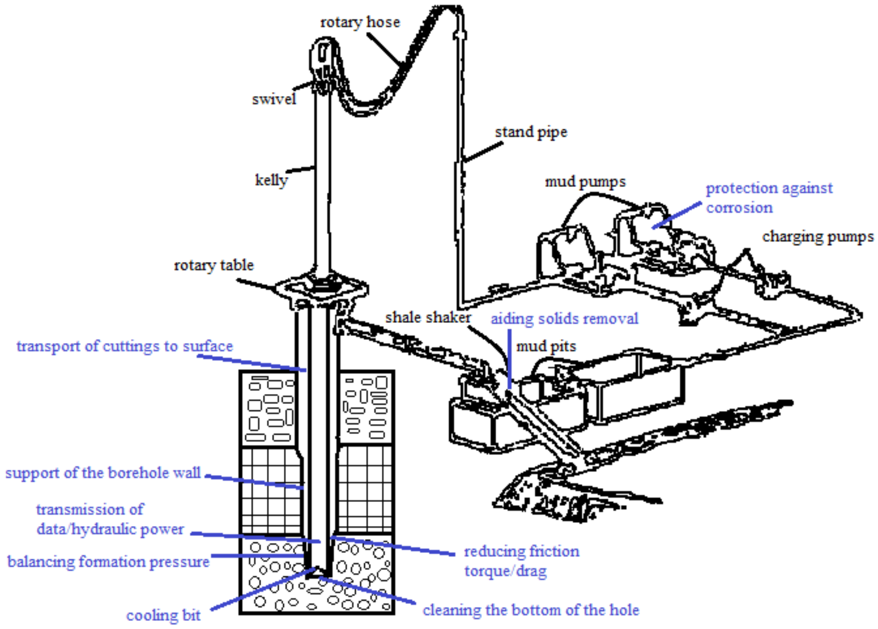

Fig.1: Functions of drilling mud (Karkare, 2016)

2.4 Drilling Fluid Circulation System

Dyke (2003) presented in his book the drilling fluid circulation systems with the different equipment (mud tank, mud pumps, mud pits, mud-mixing equipment and contaminant removal equipment) that the drilling mud passes through it as shown in figure 2. First, drilling mud is stored in mud tanks existed near the rig then, mud pumps force the drilling mud at high pressure to the pump manifold which located at the derrick floor. From the manifold, the mud reaches the rig within the standpipe, after that, the mud passes in the drill string through swivel (permits rotating the drill string while the fluid is pumped down) which present at the top of the Kelly. Then, the drilling mud passes down through the rotating drillstring to the drill bit at the bottom of the hole. The drilling mud then travels up to the surface through the annular space between the borehole wall and rotating drillstring and finally to the suction mud tank through the shale shaker (separate the cuttings from the drilling mud).

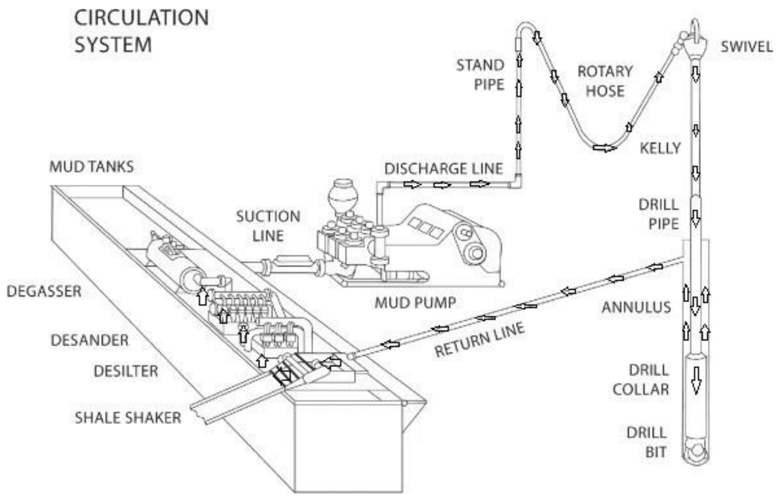

Fig.2: Drilling mud circulation system (McBride, 2012)

2.5 Types of Drilling Muds

Azar and Samuel (2007) studied in the book “Drilling Engineering” how the mud system should be selected for a specific well based primarily on the following three key factors technical performance, nature of the rock formation, financial implications and the environmental constraints. Therefore, different types of drilling mud (three families) were formulated according to their use and composition as shown in table 2.

The first family which is the water-based mud (WBM) family also known as aqueous drilling fluid. It has fresh, salt, or sea water as a continuous phase. It is used in most offshore rigs due to its nature of being environmentally suitable, good penetration rates and cheaper than other type of muds. Generally, it consists of fresh of salt water, clay (bentonite), barite, caustic soda, lignosulfonates, lignite, with different types of additives based on the well conditions and reservoir properties. The main drawback of water-based muds is that they are reactive to clays and lead to time-dependent borehole problems.

The second family consist of both the oil-based mud (OBM family) and Synthetic-based mud (SBM). oil-based mud has diesel fuel or low toxicity mineral oil as a continuous phase, it contains less than 5% water. OBM give better performances than WBM such as greater shale stability and excellent lubrication, but they have many drawbacks such as more expensive than other muds and cause many environmental problems (so many researches worked in this area to make this mud respond to environmental regulations). But the Synthetic-based mud is a mud where the synthetic oil (ester, olefins or paraffins) is the base fluid. SBM is the most one used on deep offshore rigs because of its lower toxicity compared oil-based muds. SBM and OBM have the same environmental concerns, wellbore stability and rate of penetration but they differ in their toxicity.

The third family which is the drilling fluid that contains gas, aqueous foams or classical muds with nitrogen. This type of mud is used in underbalanced drilling when the pressure is required to be lower than the pore pressure. It has many advantages over other types of muds such as higher penetration rates, lower formation damage, no circulation loss and preferred for poorly fractured formations.

Table 2: Types of drilling mud (IET, 2016)

	family First			family Second		family Third
	Water-based			Oil-based	Synthetic-based	Gas-based
Application worldwide	50% of wells			10%	30% (mostly deep offshore)	10% of wells
Types/base	HPWM	Non-dispersed systems	Dispersed systems	Diesel or mineral low toxic oil	Ester, olefins, paraffins	Air, mist, foam, classical mud with nitrogen
Key reasons for selection	-improved rheology -well/hole stability -moderate temperature	-inhibition issues -high salinity -logistical challenges	-toPHole drilling -low cost and simple -spud mud	-high temperature -well/hole stability -torque and drag -better lubrication -increased ROP	-high temperature -well/hole stability -torque and drag -better lubrication -increased ROP -offshore disposal challenges	- underbalanced drilling -high penetration rate -low formation damage -no circulation loss - poorly fractured formations
Cost	Medium to high	Low	Low	high	High	High

Drilling efficiency	Medium to high	Low to medium	Low to medium	high	High	Medium
Rate of penetration	Medium to high	Low	Low	high	High	High
Wellbore stability	Medium to high	Low to medium	Low	high	High	High
Environmental concerns	Low to medium	Low	Low	high	Medium to high	Medium

2.6 Oil-Based Muds vs Water-Based Muds in HPHT

Amani et Al. (2012) make a comparison between oil-based mud and water-based mud in HPHT fields because the rheological properties of the drilling mud are highly affected by the combined pressure-temperature when drilling into deeper formation. This provides a wide range of mechanical issues and difficult challenges. Results show the advantages of the application of oil-based mud over water-based mud which are faster penetration rate, more shale stability, providing better gauge hole and higher lubricity but water-based fluids can break down and cause loss of both viscosity and fluid control at HPHT conditions. However, oil-based fluid is not always workable due to its high cost because those formulations based on expensive synthetic fluids, kick can’t be detected in those formulation due to high gas solubility in drilling fluid. In addition, great environmental concerns take place when using oil-based fluids as related to loss of whole mud, discharge of cuttings and disposal of oil-base fluid. Also, oil-based mud damage the rubber parts of the circulating system.

So, it is necessary to add more rig equipment to minimize the loss of oil-based fluid.

2.7 Effect of Drilling Mud on Wellbore and Formation

Caenn et al. (2017) emphasized in the first chapter of his book “composition and properties of drilling and completion fluids” the mud’s effect on the wellbore and the formation during drilling as shown in table 3. They mainly focus in their study on density, viscosity, rheology including plastic viscosity, yield point, gel strength, filtration and PH.

Density: The weight per unit volume of mud. It is the most important property of the drilling mud because it is the responsible in controlling the formation pressure by adjusting the hydrostatic pressure of the mud which is related directly to the weight of the mud (Hydrostatic Pressure (HP) = Mud weight (PPG) x 0.052 x TVD (ft). The drilling fluid density must be adjusted in order to stay in overbalanced situation to avoid the influx of formation fluid into the wellbore, also to avoid lost circulation into the formation which occur when hydrostatic pressure is higher than the fracture pressure of the formation. downhole conditions do not highly affect density, since the effects of increased temperature and pressure oppose each other and tend to equalize (Annis, 1996).

Viscosity: The resistance of the fluids to flow. Between layers of liquid, it is the measure of the internal friction developed by sliding layers and it shows the thickness of the fluid (ASME Shale Shaker Committee 2004)

Rheological properties: The flow characteristics of the mud under different flow conditions. In circulating system, flow occurs at different rates in different conduits size and shapes. To predict the effects of this flow, it is important to study the flow behavior of the mud at different points in the mud circulating system. When the fluid flows, it exerts a shear stress. It is the frictional drag exerted on the surface of conduit. Its magnitude depends on the frictional drag between adjacent layers of fluid moving at different speeds, and the difference in velocities of adjacent layers next to the wall of the pipe. The difference in velocities between adjacent layers is called shear rate. The interest is focus in the effect of flow at the wall where both shear rate and shear stress are maximum.

Plastic viscosity: The measure of the flow resistance of a mud which caused by the friction between the suspended particles and the viscosity of the continuous liquid phase. According to the Bingham plastic model, PV is the slope of the shear stress/shear rate line above the yield point. According to them, Plastic viscosity increased when the solid particles in the drilling mud such as viscosifiers, lost circulation material, drill solids increase, so the aim is to decrease its value by reducing the solid content which can be achieved by diluting drilling fluid or using solid control equipment. It decreased with increasing temperature, due to thinning of water. It is the predictable behavior of mud at the bit and affirmed that to minimize high shear rate viscosity, the plastic viscosity must be minimized. Decreasing the plastic viscosity, leads to reduction in the viscosity at the bit resulting in higher rate of penetration. So, drilling fluid has to be viscous enough to carry the cuttings to the surface, but at the same time, viscosity must not be too high in order to decrease friction pressure loss.

Yield point: The ability of the stress to move the initial resistance flow of drilling fluid, also defined it as the attractive force among colloidal particles in drilling mud. It indicated the strength of a drilling mud to transport cuttings to the surface at dynamic conditions. It depended on the type of solids present, their respective surface charges and concentrations, also on the type and concentration of ions that may be present. As per Bingham plastic model, YP is the shear stress extrapolated to a shear rate of zero, which means any change in the low shear rate viscosities will be reflected on it so yield point is a good indicator of the flow behavior in the annulus.

The particles bind together at low shear rates, while the particles bonds broke at high shear rates, so the integration of these two effects define the yield point of the drilling mud. Mechanical and chemical treatments are used to control the interaction of the solids. Therefore, flocculation of clay solids causes high yield point.

The two major functions associated with yield point are cleaning the bottom of the hole and controlling the pressure of the mud.

Gel strength: The ability of the drilling fluid to hold drills solids and weighting agent in suspension when circulation stops. This is critical for making connections as drilling crew may stop circulations from 2 min up to 7 min. According to the Bingham plastic model, the gel strength is the shear stress of drilling mud that is measured at a low shear rate after the drilling mud has been static for a certain period of time (10sec and 10min in the standard API). In the case of water mud, the gel strength increased when flocculation begins to appear, while it decreased during DE flocculation.

Filtration: The occurrence when a formation is exposed to a hydrostatic pressure higher than its pressure, which makes the filtrate to flow into the formation and solid mud particles deposited on the borehole walls which expressed as filter cake. The different problems that occur during drilling due to the invasion of filtrate and to the deposition of mud cake.

The main problems caused by filtrate invasion into the formation layer are: Formation evaluation and logging will not be accurate due to the excessive fluid loss into the formation which causes flushing of the zone around a wellbore. Also, the invasion of the filtrate into the formation causes a reduction in the formation permeability, so the volume of filtrate is not as important as the type of filtrate.

The filter cake may cause a lot of problems such as differential pressure sticking, torque and drag, lost circulation, and poor primary cement job. The aim is to minimize the thickness and permeability of the deposited cake. High solids content can cause the fluid loss to be low but result in a thick cake. Low Gravity Solid not properly managed by the solid control equipment at surface which modify significantly the filtration properties. For drilling operations, the properties of filter cake are more important than the properties of filtrate.

PH: The measure of the hydrogen ion concentration in a solution which indicates the alkalinity or acidity of fluid (Sørensen, 1909). The solution is neutral (pH=7) when the concentration of H+ & OH- are the same, solution with a pH below 7 is considered as acidic, while the solution with a pH above 7 is defined as alkaline. The drilling mud should be developed by mixing it with additives and water to get a pH level between 8 and 10 to provide a proper yield and to achieve the required chemical reaction.

Table 3: Mud properties controlling technical key functions (Caenn et al., 2017)

Properties		**Functions**
Density Filtration Parameters Free water capacity	→	Borehole wall stabilization/support Balancing formation pressure

Rheological properties . Viscosity . Thixotropy	Cleaning the bottom of the hole Transport of cuttings to the surface Cooling the drill string and bit Hydraulic power
Chemical composition pH physico-chemical parameters	Protection against corrosion Indicate the alkalinity or acidity of mud
Lubricity coefficient	Reducing friction/torque and drag

2.8 Mud Related Drilling Problems and Solutions

Hossain and Islam (2018) studied in their book the different problems and solutions that related to the properties of the drilling mud, such as formation damage, corrosion and lost circulation as shown in table 4.

Formation damage: The invasion of mud filtrate or mud solid into the formation is the main cause of the formation damage. When the mud solids invade the formation, the pores can be plugged, also the permeability is reduced due to the swelling of formation clays in the reservoir. During completion procedures, precipitation of solids can occur as a result of mud filtrate with other fluids, such as acids or brines. The interaction between the formation fluids and the mud filtrate restricted the permeability.

Prevention: Formation damage can be managed by using drill-in fluids. These fluids were formulated to avoid the excessive fluid penetration into the formation, they contain additives that essential for filtration control, have clay or shale inhibitors, contain non-damaging polymers and bridging agent.

Corrosion: Corrosion is the major cause of drill-pipe failures. It occurs during the degradation of organic additives in drilling mud by bacteria or high temperature which result in corrosive products. Also, contamination by acid gases (hydrogen sulphide and carbon dioxide) and by formation brines can cause sever corrosion. Under adverse conditions, the replacement of a new drill pipe becomes an economic problem.

Prevention: corrosion can be reduced by raising the pH of mud, reducing dissolved oxygen in the drilling fluid by using vacuum degassing which aimed to remove the gas cut from the mud when static mud weight is not balancing the reservoir pressure and oxygen scavenger can be used though (sodium nitrite or sodium sulfite) and addition of corrosion inhibitors such as zinc carbonate, filming amines, sodium molybdate and sulfide scavengers.

Lost circulation: It is a situation when part or entire volume of drilling mud losses through borehole into fractured, cavernous or highly porous formation as a result of excessive hydrostatic pressure. It is characterized by a reduction in the return of the mud rate from the well with respect to the original rate at which the mud is pumped downhole.

Prevention: Lost circulation can be managed by reducing mud density, lowering gel strength and avoiding pressure surges, also by the addition of lost circulation materials such as fibrous (raw cotton or mineral fibers), flaky (mica, cotton seed hulls or cellophane), granular (perlite, wood or nut shells) or thick slurry pills (bentonite or cement).

Table 4: Drilling fluid problems and solutions (Hossain, 2018)

Problems	solutions
Formation damage	Using drill-in fluid
Corrosion	Raising the pH of mud Using vacuum degasser and oxygen scavenger
Lost circulation	Reducing the mud density Lowering gel strength Avoiding pressure surge Using lost circulation materials

2.9 Alternative Weighting Materials

Various researches and articles were conducted to find an alternative weighting material that meet the well conditions and the environmental constraints. In recent years many experiments have done for new weighting materials instead of the original material (barite) which differ in its density, hardness and solubility. Thus, shedding light on finding a new weighting material gained the interest on many researchers to work on.

Mined iron oxide: First, Walker (1983) studied the ability of using mined iron oxide as a weighting agent instead of barite. The only observed benefit of this material was its high density comparable to other materials, so it can be used as an alternate of barite and less amount of material is required to increase density which in turn reduce costs but should be take care to the fracture pressure of the formation.

Hematite: Then, Watts and Sharf (1984) presented the importance of using hematite as an alternative weighting agent in heavy oil muds. Many experiments have done to make a comparison between hematite and barite. Results indicate that hematite give lower rheology properties (Gel strength, yield point and plastic viscosity) than barite, which result increasing in penetration rates and improving bit hydraulics.

Ilmenite: Saasen et al. (2001) studied the application of using ilmenite as a weighting agent in water and oil muds. The use of ilmenite gives higher penetration rate due to the production of less colloidal solid fractions during drilling, also it has good rheological properties compared to barite which give the possibility of using this material as a weighting material instead of barite.

Manganese Tetra oxide: Al-Yami and Nasr-El-Din (2007) assessed the possibility of using Manganese Tetra oxide as a weighting agent in water-based muds. Results indicate that this material has better thermal stability than barite. The use of the mix Mn_3O_4 with $CaCO_3$ improved the filtration and reduced the thickness of the filter cake. Experiment show that starch polymers are better than the old polymers to get better filtration control for this material.

Formate brines: Al-Muhailan et al. (2014) presented the different types of formate brines used and their advantages. Formate are highly soluble in water, resulting in high density brines. Three formate brines are used in the drilling industry, namely sodium formate (with densities up to 10.8 ppg), potassium formate (maximum density of 13.3 ppg) and cesium formate (maximum density of 19.2 ppg).

The formate brines outperform traditional drilling fluids by delivering a number of important benefits in the oil wells; such as Low equivalent circulating density and low viscosity, stabilize polymers at high temperatures, low corrosivity, good shale inhibition with low water activity, high tolerance to solids contamination.

Cesium formate based brine was not chosen due to significantly higher cost and the risk of severe down hole losses when using such a costly fluid in exploratory wells.

Galena: Akpabio Julius et al. (2015) studied the ability of using galena as a weighting material instead of barite in a drilling mud. Results indicate that this material can be used instead of a barite because smaller quantity of galena could produce same mud weight as barite. Most of the rheological characteristics are the same to that of barite but galena gives a higher gel strength and yield point which can be decreased by increasing the concentration of lignosulfonate. The advantages of galena over barite is their abrasive characteristics and its lower solid content.

Dolomite: Abdou and El Sayed Ahmed (2017) presented the ability of using dolomite as a new weighting agent for water-based muds. The results showed that this material can be used instead of barite because the rheological properties of dolomite and barite are the same, but the solid content of barite is smaller than of dolomite of the same quantity. Dolomite cause high filtration loss into the formation which can be treated by PAC additive. The main drawback of using this material is that it is sourced especially in Egypt and not spread wide over the world which disables the interest of using it outside Egypt.

Barite and ilmenite mixture: Abdou et al. (2018) presented the impact of using barite and ilmenite mixture (BIM) on enhancing the drilling mud weight. Results indicate that BIM has the potential to be used in place of barite only because this mixture gives better yield point and gel strength than barite, also lower solid content than barite due to its high specific gravity. This mixture showed appropriate filtration loss and mud cake characters which in turns reduces the formation damage.

3. ADVANTAGES OF SIDERITE OVER BARITE

Sample (1982) examined the advantages of the material "siderite" over barite. In general, the drilling mud should not be damaging to the formation, so the work involved is to find an alternative weighting agent instead of barite which contains a high amount of insoluble solid which cause invasion of mud solids into the formation. The invasion of mud solids into the production zone cause a degradation of return permeability in the production zone and can block pore holes, the invasion of mud fluid into the formation cause a change in the wettability of the formation change due the emulsion block and cause a swelling of clay in the formation. So, the mud solid invasion into the production zone cause high reduction in permeability. Also, insoluble weighting agents can cause a damage in the filter cake which in terms reduce the efficiency of well stimulation techniques. So, the work is involved in adding new materials or alternate some materials to solve this type of problem that occur during drilling. Then, they used calcium carbonate as weighting agent in drilling mud alternative of barite due to its acid solubility. So, by using it, the filtrate and the fluids/solids that penetrate the productive zone can be dissolved but because of its low density (2.7 g/cc), drilling mud includes calcium carbonate is limited.

After that, a mix of calcium carbonate and barite have been used to get higher density, but this mix contain a high amount of acid insoluble particles due to the presence of barite. He confirmed that a weighting agent should have high density, high acid solubility and have compatible with both oil and water muds. He talked about the ability of introducing a new weighting material "siderite" to the drilling mud because it has the unique property of being complete solubility in organic and mineral acids and its ability of being removable from the bottom hole of the wellbore. It can be used in both water and oil-based muds due to its high density (3.8 g/cc) which permits formulation do drilling mud weights up to 19 lbs/gal.

4. RECOMMENDATIONS

Fields with very high formations pressure necessitate a higher hydrostatic pressure to help maintain a safe margin and prevent "kicks". So, problems such as low specific gravity of siderite compared to other materials in these fields can be managed by mixing siderite with barite or another one has a high specific gravity to get a high hydrostatic pressure and high solid solubility at the same time. The weighting material "siderite" should be the center of researches in the future since there are no recent experiments highlighting the physical properties of interaction of siderite with other weighting materials.

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