The Effect of Environmentally Friendly Additives on the Rate of Fluid loss and the Rheological Properties of the Drilling Fluid

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Abstract—Because of the increased pollution risks associated with drilling for oil and gas wells, both on land and at sea, especially when an oil spill occurs, and due to the tightening of environmental regulations, it has become necessary to work on finding environmentally friendly drilling fluids. As it is well known that is the rate of fluid loss and rheological properties are among the most important factors affecting in reducing leakage and pollution of the surrounding environment, so that the current study aims at reviewing and finding the environmentally friendly additives that could be add to the drilling fluid to improve both the rate of fluid loss and the rheological properties. Among these interesting additions were the date seed powder (DSP) which reduced the rate of fluid loss by 40% roughly improved the rheological properties. As well as the grass powder (GP), which reduced the rate of fluid loss by 42% at a concentration of 0.5% in LTLP experiments, while in HTHP experiments it achieved a reduction of 26%, 35%, and 43% of concentrations 0.5%, 1%, and 1.5%, respectively. It also improved rheological properties by increasing PV by 39% at a concentration of 1.5% and YP by 12%, 18%, and 48% at 0.5%, 1%, and 1.5%, respectively. The same case with NAT-20 environmentally friendly when adding 1% to 4% of bentonite, fluid loss before and after aging was (5.6 - 4.8) ml. In the case of using an environmentally friendly synthetic polymer whose chemical composition (Terpolymer of acrylamide, sulfonated monomer, vinylpyrrolidone) the fluid loss in HTHP reached 16 mL / 30d, While PV 66 cP, YP 18 lb/100 ft^2, and 10-minute gel 22 lb /100 ft^2. In brief, these environmentally friendly additives have positive effect on improving the fluid loss and rheological properties.

Index Terms— Biodegradable waste, Drilling fluid, Eco-friendly additives, Fluid loss additive, Food waste, Rheological Properties

1 Introduction

THE increase in the global demand for oil and gas led to a search for more energy resources and in new areas, and as a result exploration towards marine sites began. As well as drilling techniques evolved from traditional vertical drilling to extended-reach drilling (ERD), which in addition to imposing challenges such as difficult to advance drilling under conditions of high pressure and high temperature (HPHT), increasing the possibility of environmental threat due to drilling fluids to be used to suit the conditions of this type of drilling from pressure and heat, as well as ensuring the protection of pipelines from potential malfunctions and the risk of corrosion.

Drilling fluid in rotary drilling serves multiple functions. It carries cuttings from under the rotary bit, transports them to the annulus, and allows their surface isolation while simultaneously cooling and cleaning the rotary bit. It decreases tension between the drill string and the borehole sides. In addition, the following tasks are done by drilling mud; seals permeable formations decreases filtrate invasion, preserves the integrity of uncased borehole sections, minimizes damage to the reservoir. By forming a thin, low permeability filter cake that blocks pores and other openings in the formations penetrated by the drill bit, it ensures sufficient formation assessment and reduces the leakage of drilling fluids through the permeable formations. Bourgoyne et al. (1986).

Since the 1990s, the development of drilling fluids has continued such as format fluid drilling system, polyvinyl alcohol (PVA)/silicate fluid drilling system, polyolefin fluid drilling system, ether-based fluid drilling system, ester-based fluid drilling system, etc. Both of these fluid systems have similar features, such as low toxicity, fast deterioration, and little environmental effects. (Zhenjie. 2004; Ling et al. 1999; Jiankang and Jienian. 2003; Jianshan et al. 2002; Jun et al. 2001; Chao et al. 2002; Leliang and Guijuan. 2003, (1); Leliang and Guijuan 2003, (2); Wenfa et al. 2000; Ying. 2001).

However, it has not been widely used, due to the high cost or unsatisfactory application effects (cannot fully satisfy engineering needs). After Strict rules on additive drilling have been released by the United States Environmental Protection Agency (EPA). materials and their waste, it became imperative for the oil industry to come up with a new solution and change its practices To decrease the impact Drilling waste, which is the second-largest amount of waste generated, Haut et al. (2007). Especially It takes a lot of time to recover the ecological equilibrium in the ecological catastrophe zone, and major events are capable of tilting our planet's ecological balance at both. As a result, In contrast to non-environmentally safe drilling fluids such as oil-based muds, researchers have begun designing new eco-friendly drilling fluid systems. (Bland et al. 1995; Van Oort et al. 1996; Nicora and Burrafato, 1998; Thaemlitz et al. 1999; Hector et al. 2002).

Developing and screening criteria for drilling fluid additives have been determined in compliance with the specifications of the engineering operation and the environment: (1) environmentally-safe, i.e. light color, non-toxic (biologically and chemically non-toxic), easily degradable; (2) No debris for mixing with water forming, good anti-swelling and plugging ability, less environmental damage; (3) less forms of chemicals, easy-to-prepare drilling fluid; (4) The fluid system has good performance, consistent consistency, and simple maintenance. Shuixiang et al. (2011).

Thus, according to these fundamentals, the researchers began to try to find the best synthesis of an environmentally friendly, low-cost drilling fluid that meets the needs of drilling engineering.

In this paper, we will study the most important environmentally friendly additions to drilling fluids and their effects on fluid loss factor and Drilling fluid's rheological properties, such as plastic viscosity (PV), yield point (YP), power of gel, and others.

2 The applications of waste materials in the oil and gas industry

Instead of disposing them to the environment, waste products can be used for many uses in the oil and gas industry, including, though not limited to, food waste that can be used for other purposes such as drilling and finishing fluid additives Al-Hameedi et al. (2019a). Al-Hameedi et al. (2019b) The use of Mandarin Peels Powder (MPP) to fight filtration properties and rheological requirements for mud was studied. Based on their findings, the MPP increased the rheological properties of mud and minimized the loss of seepage, meaning that MPP should be used as a drilling fluid additive. Another example of a food waste additive is Potato Peels Powder (PPP) discussed by Al-Hameedi et al. (2019c). Their findings revealed that the PPP had little effect on mud weight, but by optimizing the plastic viscosity and minimizing the yield point, it had an effect on the rheological properties. In addition, the leakage of fluid has been minimized, rendering it an efficient drilling fluid additive.

Further tests have been performed on biodegradable waste material as substitutes for drilling fluids to minimize drilling waste. Iranwan et al. (2009) The use of corn cobs and sugar cane as viscosifier control was assessed. However, their findings found that the viscosity of plastic improved while the strength and yield point of gel decreased. Nmegbu and Bekee, (2014) The use of corncob cellulose in water-based drilling fluids has been clarified. Their findings showed that, as opposed to polyanionic cellulose (PAC), the new filtration control agent was effective in reducing fluid loss. Omotioma et al. (2014) The result of including the extract of cashew and mango leaves was studied, which enhanced the rheological properties of the mud. Okon et al. (2014) The probability of using rice husk as an additive for regulating filtration properties was investigated. Their findings revealed that, when 20 parts per billion (ppb) concentration was applied and compared to CMC and PAC, the rice husk was able to minimize fluid loss by 65 percent. The rice husk, however, may result in an unnecessary impact on the viscosity of the plastic. Adebowale and Raji. (2015) The use of banana peel ash as an alternate drilling fluid was examined to monitor corrosion and increase pH. After applying banana peel ash, the findings obtained indicated an increase in pH. Nyeche et al. (2015) To strengthen mud properties, the use of potato starch derived from potato tubers was tested. With 2 ppb of PAC, the additives were combined. Nonetheless, their findings found that potato starch reduced the filtration and rheological properties of mud. Moslemizadeh and Shadizadeh. (2017) Investigated the effect of using henna extract as an environmentally sustainable shale inhibitor in water-based muds. Their studies found that henna was capable of minimizing swelling of the shale and enhancing lubricity. When applying 10 ppb of henna extract, a small increase in the loss of fluid was observed while decreasing the rheological properties of the mud. Sampey. (2006) Sugar cane was tested to be used in well-working formulations for filtration control. Such food waste products have also been tested, such as tamarind gum, coconut coir, peach pulp, soybean peel, olive pulp, and pomegranate peel. (Sharma and Mehto, 2004; Macquiod and Skodack, 2004; Morris, 1962).

3 The effect of additives on the properties of the drilling fluid

3.1 Selection of fluid loss agent

The aim is to monitor the filtration, not to avoid it entirely. Thus, the drilling mud should be ideally built to economically execute the desired functions. An increasing concern in the oil and gas industry is excessive fluid depletion. Some chemical additives are used to regulate fluid loss, such as bentonite, carboxymethyl cellulose (CMC), and starch, to prevent high levels of fluid loss. Moore. (1986).

Amanullah et al. (2016) Date seed powder (DSP) has been tested as an eco-friendly fluid loss additive extracted from an indigenous raw material for drilling muds dependent on fresh and saltwater, With a particle size of fewer than 150 μm, the date seed powder has been applied and is readily dispersible in an aqueous medium at a low to moderate shear rate. By formulating clay-free fresh and salt water-based drilling muds and then performing API tests at room temperature and 100 psi overbalance pressure and high-pressure high temperature (HPHT) fluid loss tests at 100 ° C (212 ° F) and 500 psi overbalance pressure, the suitability of the additive was tested. The analysis of clay-free Water + XC1 and Water + XC1 + DSP6 spurt loss activity shows 90 cc API spurt loss for the XC containing method, but just 9 cc API spurt loss after applying DSP to the Water + XC1 clay-free system. This is around a 90% reduction in API spurt failure due to DSP involvement. This certainly shows the use and suitability of DSP for water-based drilling fluid systems as a fluid loss additive or additive substitute. When comparing the spurt loss behavior of DSP

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containing clay-free system with a clay-free mud system containing changed srch, which is a traditional fluid loss additive, it indicates much better efficiency, around 40 percent decrease in spurt loss for DSP-containing fluid, compared to another clay-free system (Water + PHP2) with and without DSP, it indicates 2 cc spur loss for DSP-containing fluid. However, in the presence of DSP, the water + PHP2 scheme produced just 1 cc spurt loss, i.e. about 50 percent lower spurt loss. Likewise, for HPHT experiments, while in clay-free fresh and sea water-based systems FW + PHP + DSP and clay-free sea water-based muds SW+PHP and SW PHP DSP systems, the DSP helps minimize filtration by more than 50 percent. This again proves the suitability of DSP for water-based mud systems as a fluid loss additive.

Hossain and Wajheeuddin, (2016) studied effect adding grass powder (GP) in water-based muds and The findings indicated a small increase in gel strength and, at high concentrations of grass powder, the filtration properties indicated decreases of up to 25 percent. However, this study had some shortcomings that Al-Hameedi et al. (2019) addressed in their study, and compared the results of adding different concentrations of grass powder (GP) (0.5%, 1%, 1.5%) to a reference fluid (RF) with the addition of the same concentrations of starch, under conditions of low pressure and low temperature (LPLT), as well as high pressure and high temperature (HPHT), where (RF) was prepared from bentonite and NaOH.

As compared to the reference fluid for both concentrations, GP and starch contributed to a decrease in fluid loss. Fig.1 Shows the findings for LTLP and HTHP conditions of the filtrate. 0.5 % of GP additives were more effective than starch in reducing the fluid loss for LTLP filtration control experiments; where 0.5 % of GP and starch decreased filtrate (cc/30min) by 42 % and 28 %, respectively; while 1 % and 1.5 % of GP and starch additives had about the same efficiency in reducing the loss of seepage relative to the reference fluid

The GP blend was the best filtration control additive for HTHP filtration control tests, where fluid loss (cc/30min) was decreased by 26 %, 35 %, and 43 % at 0.5 %, 1 %, and 1.5 % concentrations, respectively, relative to the reference fluid. However, the starch additive recorded a 3 %, 23 %, and 34 % rise in fluid loss (cc/30min) at 0.5 %, 1 %, and 1.5 % concentrations. In relation to the reference fluid, Which implies that when comparing it with the starch for sub-surface

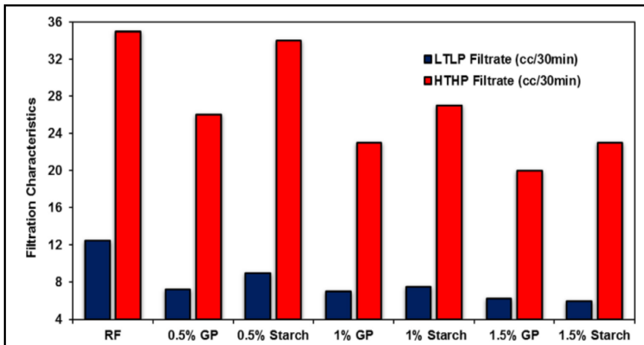

Fig. 1. Effect of GP and starch on filtrate (LTLP and HTHP conditions). (Al-Hameedi et al., 2019)

conditions using different concentrations, GP obviously had better efficiency.

Shuixiang et al. (2011) added three environmentally friendly fluid loss factors, (NAT-20, SZDJ-2, ZX-1) at 1.0% each to 4% of the bentonite liquid, and these fluids were measured after the filter was lost. Filter losses again after a fluid lifetime at 120° C for 16 hours, which aims to compare filter losses before and after aging. The fluid loss achieved by NAT-20 before and after aging (5.6 - 4.8) ml, respectively, while when adding the ZX-1 was a fluid loss. (6.6 - 6.0) ml, and by adding SZDJ-2 (7.8 - 7.7) ml, as for the thickness of the clay cake, the result was the same for all additions, which is 0.5 mm. Therefore, NAT-20 additive was adopted as a fluid loss agent, because the filter control ability of NAT-20 was better than ZX-1 and SZDJ-2, and NAT-20 fluid losses were lower before and after aging. Tehrani et al. (2009) A new high-density HPHT water-based fluid system, chrome-free, has been developed. In order to provide excellent fluid loss control and produce thermally stable rheology, the current fluid uses a mixture of clay and silicone polymers, depending on the degree of crosslinking between the products. As observed by Thaemlitz et al. (1999) In copolymer solubility, which is related to the ability to regulate fluid leakage, the degree of crosslinking plays a significant role. Six synthetic polymers (their functions are controlling rheology, controlling fluid loss, in addition, filter cake sealing) have been used in tap water, clay, barite, and a number of additives to formulate six water-based drilling fluids of 18.0 psi/gallon (2157). Kg / m^3). Thermal stability and filtration control were tested by exposing water-based drilling fluids prepared with the above materials to elevated temperatures over a period of time. Liquids were combined in one laboratory quantity (350 ml) and at 450 ° F for 16 hours in a revolving oven. HPHT fluid loss was estimated at 350 ° F, 500 psi for aged liquids. In terms of plastic viscosity (PV), yield point (YP), 10-minute gel, and fluid loss, parameters for accepting fluid characteristics were set. In general, PV is preferred to be as low as possible, but values up to 70 cP are appropriate provided the high fluid density. For 10 minutes, the upper limits of YP and gel were set at 20 and 40, respectively. With HTHP estimated at 350 ° F 20 ml, the fluid loss did not exceed 30 minutes. Liquids demonstrated strong variations in the efficiency of rheological regulation and fluid loss on these laws, the best of which was Fluid # 3.

Polymer D is responsible for controlling the loss of the liquid and its chemical composition (Terpolymer of acrylamide, sulfonated monomer, vinylpyrrolidone) in Fluid #3 gives better performance compared to other fluids as Fluid #3 meets all desired acceptance criteria, in terms of HPHT loss Fluids which is 16 mL / 30d, s, while PV 66 cP, YP 18 lb/100 ft^2, and 10-minute gel 22 lb/100 ft^2.

3.2 Rheology, (PV), (YP)

In this section, the effect of additives to drilling fluid on both rheology, Yield point (YP) plastic viscosity (PV) was investigated. Al-Hameedi et al. (2019) studied the GP additives, and their effect on rheological properties. Experimental findings found that 0.5 % and 1 % of GP additive concentrations had the same negligible effect on PV, while 1.5

% of GP had a 39 % modest rise in PV relative to the reference fluid. In the same way, in contrast to the reference fluid, YP rose by 12 %, 18 %, and 48 % at 0.5 %, 1 %, and 1.5 % concentrations, respectively. It can be shown that in increasing rheological properties, starch was more efficient than GP, as seen inFig.2Amanullah et al. (2015) investigated the addition of the date seed powder (DSP) to mud with 100 g of barite for high-density applications to see the applicability of the mud. Strong rheological properties with PV and YP values of 10.2 and 23.3 respectively are seen in the prepared weighted mud. For 10 s (7.9) and 10 min (8.7), the difference in gel intensity is minimal. This ensures that the mud has no substantial gelation over time.

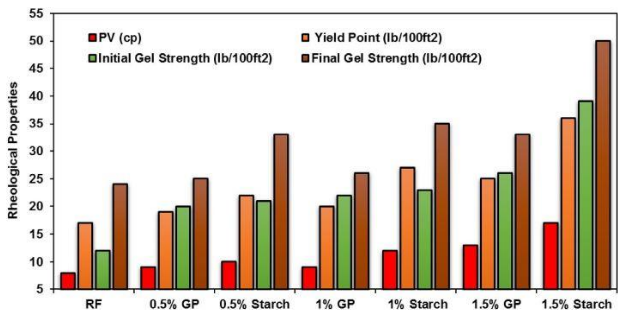

Fig. 2 The effect of GP and starch on rheological properties (Al-Hameedi et al., 2019).

Table 1 shows the results obtained by Al-Hameedi et al. (2019) and Amanullah et al. (2015) in their study about the effect of the used materials on the rheological properties of drilling mud.

TABLE 1
The effect of the materials used on the rheological properties of drilling mud.

Rheological Properties	0.5% GP	1% GP	1.5% GP	DSP
Mud Density, (*ppg*)	8.6	8.6	8.5	9.8
PV, (*cp*)	9	9	13	10.2
YP, (*lb/100 ft*^{2})	19	20	25	23.3
Initial Gel Strength, (*lb/100 ft*^{2})	20	22	26	7.9
Final Gel Strength, (*lb/100 ft*^{2})	25	26	33	8.7
References	Al-Hameedi et al. (2019)			Amanullah et al. (2015)

Conclusion

In this study, the effect of environmentally friendly additives on drilling fluid properties including; fluid loss rate, and rheological properties were investigated. The effectiveness of such additives is presented in achieving the desired improvements on drilling fluids, as it has been able to reduce the rate of fluid loss in good proportions, and even they have a slight improvements in the rheological characteristics if it's compared to the influence of starch widely used. Therefore, we can confirm the feasibility of using environmentally friendly materials as additives to drilling fluid which can achieve operational requirements at a relatively low cost and at the same time preserve the surrounding environment as most of these materials are available in large quantities or they are easy to prepare.

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