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ORIGINAL PAPER

The use of grass as an environmentally friendly additive in water-based drilling fluids

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Abstract Excellent drilling fluid techniques are one of the significant guaranteed measures to insure safety, quality, efficiency, and speediness of drilling operations. Drilling fluids are generally discarded after the completion of drilling operations and become waste, which can have a large negative impact on the environment. Drilling materials and additives together with drill cuttings, oil, and water constitute waste drilling fluids, which ultimately are dumped onto soil, surface water, groundwater, and air. Environmental pollution is found to be a serious threat while drilling complex wells or high-temperature deep wells as these types of wells involve the use of oil-based drilling fluid systems and high-performance water-based drilling fluid systems. The preservation of the environment on a global level is now important as various organizations have set up initiatives to drive the usage of toxic chemicals as drilling fluid additives. This paper presents an approach where grass is introduced as a sustainable drilling fluid additive with no environmental problems. Simple water-based drilling fluids were formulated using bentonite, powdered grass, and water to analyze the rheological and filtration characteristics of the new drilling fluid. A particle size distribution test was conducted to determine the particle size of the grass sample by the sieve analysis method. Experiments were conducted on grass samples of 300, 90, and 35 μm to study the characteristics and behavior of the newly developed drilling fluid at room temperature. The results show that grass samples with varying particle sizes and concentrations may improve the viscosity, gel strength, and filtration of the bentonite drilling fluid. These observations recommend the use of grass as a rheological modifier, filtration control agent, and pH control agent to substitute toxic materials from drilling fluids.

Keywords Rheology · Filtration · Filter cake · Apparent viscosity · Plastic viscosity · Gel strength

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1 Introduction

The use of drilling fluids (DFs, also called drilling mud) is an essential part of a rotary drilling process. Different types of chemicals and polymers are used in designing a drilling fluid to meet functional requirements such as appropriate mud rheology, density, mud activity, fluid loss control property, etc. (Amanullah et al. 1997). Today, the choice of drilling fluids and their additives has become complex (Caenn et al. 2011), considering both the technical and environmental factors (Amanullah 1993).

The preservation of the environment on a global level is now important as various organizations have set up initiatives to drive the usage of toxic chemicals as DF additives. Environmental pollution has been considered a serious threat while drilling complex wells or high-temperature deep wells, which are now managed by using oil-based DF systems and high-performance water-based DF systems. As environmental protection has become a consideration before any oil and gas resources exploration, people have paid more and more attention to the DF for environmental safety. Advances in recent technologies led to the development of novel environmentally friendly DF systems (Kok and Alikaya 2003; Zhao et al. 2009; Lan et al. 2010). However, problems such as complicated treating chemical synthesis technology, the lack of raw material for treatment agents, and high initial cost have limited the development of the DF (Li et al. 2014). The application of DF for environmental protection is limited in oil resources exploration as the treating chemicals from natural macromolecular materials are often of poor quality. Synthetic and mineral oils are used in oil-based DF systems to reduce the environmental impact on the surrounding localities and the habitats. Earlier, little attention was paid to conserving the initial environmental conditions at less environmentally sensitive areas for onshore operations. However, later this delay brought the realization of negative environmental impact from DF additives such as chemicals, polymers, salt water, and oil-based fluids. Minimization of the environmental impact as well as safety considerations of a drilling operation directly affects the choice of DF additive systems. Due to the environmental regulatory agencies, products that have been used in the past may no longer be acceptable. As more environmental laws are enacted and new safety rules are applied, the choices of additives and fluid systems must also be reevaluated. To meet the challenges of a changing environment, product knowledge and product testing become essential tools for selecting suitable additives and DF systems.

There are many factors that are to be weighed when choosing a DF. However, the key considerations are well design, anticipated formation pressures and rock mechanics, formation chemistry, the degree of damage the DF imparts to the formation, temperature, environmental effects and regulations, logistics, and economics. To meet these key design factors, DFs offer a complex array of interrelated properties. Five basic properties are usually defined by the well program and monitored during drilling. These properties are listed as viscosity, density, filter cake or filtration of water loss, solids content, and quality of water make up. Once the properties and their parameters are determined, the DF can be controlled and adjusted accordingly.

2 Natural elements as additives

2.1 The need for natural substitutes

Working with DFs can be dangerous as some DF ingredients emit noxious or hazardous vapors that may reach levels that exceed the maximum recommended short-term or long-term safe exposure limits. Some shale and corrosion inhibitors and some emulsifiers in oil-based drilling fluids tend to produce ammonia or other lethal volatile amines, particularly in hot areas on a rig. Other products are flammable or combustible (flash point <140 °F) and must be handled with caution. Various mud products such as brines, cleaning agents, solvents, and base oils commonly found on drilling rigs are irritating or even hazardous to body tissues. Perilous effects of additives such as defoamers, descalers, thinners, viscosifiers, lubricants, stabilizers, surfactants, and corrosion inhibitors on marine life and human life have been reported by several authors (Becket et al. 1976; Miller and Pesaran 1980; Younkin and Johnson 1980; Murphy and Kehew 1984; Candler et al. 1992; Ameille et al. 1995; Greaves et al. 1997). These effects range from minor physiological changes to reduced fertility and higher mortality rates. Therefore, it is very important to replace toxic ingredients from conventional DFs by a truly nontoxic natural substitute. In addition, the current trend in the DF development is to come up with novel environmentally friendly DFs that will rival the present day DFs in terms of reduced toxicity levels, performance, efficiency, and cost (Apaleke et al. 2012). Several researchers proposed substitutes which give better or at least the same level of results as their toxic counterparts (see Table 1). As a result, these materials have become vital ingredients for the DF. Table 1 shows a list of these natural elements used as additives during the formulation of a DF.

2.2 Grass

Grass is the principal fodder for cattle across the globe, and its use is known to humankind for centuries. The preamble of this research is to introduce grass as an environment friendly additive in the DF.

As stated earlier, in its quest to explore hydrocarbons, the drilling industry today uses a lot of chemically toxic additives for the formulation of DFs. This leads the Environmental Protection Agencies (EPA) to closely monitor the operations of the oil and gas industry for the usage of such fluids (with high toxicity) subjecting the industry to strict environmental legislations. The objective of this research is to introduce a naturally available material (powdered grass) with low or no cost as a suitable substitute to the toxic additives used to formulate a DF. This initiative of using such a material could help in reducing the environmental concerns and improving the work environment of people involved daily in this business.

3 Particle size distribution and compositional analysis

3.1 Particle size distribution

Particle size distribution is extensively used by geologists in geomorphological studies to evaluate sedimentation and

Table 1 Use of natural elements as DF additives

Inventor	Material	Function
Morris (1962)	Ground peach seeds	Filtration control agent
Lummus and Ryals (1971)	Ground nut shells and nut flour	Filtration control agent
Burts and Boyce (2001)	Corn cob outers	Filtration control agent
Nestle (1952)	Tree bark (douglas fir)	Filtration control agent
Sampey (2006)	Sugar cane ash	Filtration control agent
Green (1987)	Ground cocoa bean shells	Lost circulation material
Burts (1997)	Rice fractions (rice hulls, rice tips, rice straw and rice bran)	Lost circulation material
Ghassemzadeh (2011)	Fibers	Lost circulation material
Cremeans (2003)	Cotton seed hulls	Lost circulation material
Macquiod and Skodack (2004)	Coconut coir	Lost circulation material
Sharma and Mehto (2004)	Tamarind gum	Viscosifier

alluvial processes and by civil engineers to evaluate materials used for foundations, road fill, and other construction purposes. In the oil and gas industry, analysis of particle size distribution is used to determine filtration loss properties, and the amount of solids retained in the DF after the fluid is pumped into the system. A DF containing particles of sizes ranging up to the requisite maximum should be able to effectively bridge the formation and form a filter cake (in the case of a water-based drilling fluid). Above 10 Darcys or in fractures, larger particles are required, and most likely the amounts needed to minimize spurt losses increase with the size of the openings. In general, with the increasing concentration of bridging particles, bridging occurs faster, and spurt loss declines (Barrett et al. 2005; Growcock and Harvey 2005). Filtrate invasion into the formation can substantially reduce the permeability of the near wellbore region either by particle plugging, clay swelling, or water blocking. Permeability of the filter cake is dependent on the particle size distribution as an increase in the particle size decreases the permeability due to the fact that colloidal particles get packed very tightly. For non-reservoir applications, enough particles of the required size range are usually present in most DFs after cutting just a few feet of rock. These particles impact the choice of various drilling equipment (i.e., shale shakers, desanders, desilters, etc.) at the surface and thus can be effectively designed by having a prior knowledge of the particle sizing in the drilling fluid (Wajheeuddin and Hossain 2014).

The literature shows that DF properties (plastic viscosity (PV), yield point (YP), and gel strength (GS)) affect the rate of penetration (ROP) drastically because the presence of unremoved drill solids can cause a phenomenon known as the chip hold down effect, which increases both the equivalent circulation density (ECD) and the differential pressure causing a decrease in the ROP. For instance, it is an established fact that the PV is influenced by the amount of colloidal particles present in the DF. Colloids present in the drilling fluid increase the fluid viscosity, which reduces the mobility of the cuttings as these cuttings stick to the bottom, requiring a re-drilling operation which severely affects the bit life. However, it is inferred that although DF properties affect the ROP, their net effect may not be as significant as it is thought to be except for the annular pressure losses in the laminar flow regime.

3.2 Use of X-ray fluorescence (XRF) in the petroleum industry

Commercial clays such as bentonite or other chemically treated clays are added to the DF for controlling rheological and filtration properties. The combined mix of commercial clays and drilled solids is called the “low-gravity solids” (LGS). Weighting materials (e.g. barite, barium sulfate, hematite etc.) are added to the fluid to make up the required density. This additive is necessary to densify mud and keeps the desired the hydrostatic pressure exerted by the DF in the drillpipe column and annulus. The concentration of these weighting materials is known as “high-gravity solids” (HGS). It is important for effective control of the properties of the fluid to know the individual concentrations of all types of solids (i.e., LGS and HGS). These entities are either measured directly or calculated from the density and volume fraction of solids in the DF, both of which can be measured but this is laborious. Traditionally, the LGS–HGS volume ratio is measured using a retort, a technique that requires good operator skills, takes at least 45 min, and has an error margin of 15 %.

The X-ray fluorescence (XRF), introduced into the oil and gas industry for analyzing core samples, is now deployed to monitor the concentrations and differentiate various solids types (LGS and HGS) in the DFs (Gilmour et al. 1996). XRF has the advantage of more frequent measurement, greater precision, and less dependence on operator skills. It is extensively used for the characterization of bentonite and other clay types for different clay applications. XRF is used to determine the elemental composition of additives to limit the usage of toxic chemicals in environmentally sensitive areas. For this purpose and due to the unavailability of the elemental composition of grass in the literature, the authors have taken the initiative to conduct XRF studies on the three said specimens.

4 Experimental methods and calculation procedure

4.1 Sample collection and preparation

Grass was collected from the Eastern Province of Saudi Arabia. The sample was dried in a sunny area for about a week, and then in a moisture extraction oven. The obtained grass was then pulverized in a grinding machine to obtain the desired grass samples.

4.2 Particle size distribution of the grass sample

Figure 1 shows a normal distribution curve of the particle size of the grass sample. Sieve sizes of 300, 180, 125, 90, 75 µm, and a no-sieve pan were used. The highest percentage of weight retained was on the 180-µm sieve, which indicates that the maximum of particles of the grass sample belonged to the medium category of particle size classification. The frequency distribution curve (Fig. 2) of the grass sample shows that at and above 50 % cumulative weight, the sample consisted of fine particles with 6 % of the sample retained on the pan (finest fraction). In order to determine the average particle size of the finest fraction, a laser particle size analyzer (PSA) was used with three attempts of measurements. The particle size is plotted on the *X*-axis of Fig. 3, while the normal and frequency distributions are plotted on the *Y*-axis (right and left of the *Y*-axis, respectively). The test reveals the average particle size of the finest fraction of grass at 50 % net weight as 35 µm, thus implying that this grass sample (comprising various particle sizes) is a suitable candidate to be tested for use as an additive in the DF.

XRF analysis of the finest grass sample reveals calcium, potassium, and chlorine as the highest contributors by net normal weight percentage. Sulfur, silicon, iron, phosphorous, and manganese are also found in this specimen as small traces. Table 2 illustrates the elements present in the grass sample. Compounds of calcium are used as bridging and weighing agents in the DF. Calcium carbonate ($CaCO_3$) is used as an inhibitor to control active shale, and calcium chloride ($CaCl_2$) is used as a clay dispersion additive. Potassium compounds are used in the DF as alkalinity control agents (potassium chloride, KCl), acidity control agent (potassium hydroxide, KOH), and weighing agents (potassium formate, $CHKO_2$). Compounds of chlorine are used as disinfectants to clean surface pipes as it is used with source materials in the form of sodium hypochlorite and calcium hypochlorite. It is also used as a polymer oxidizer for drilling, completion, and work-over clean up in the form of chlorine bleach. Silica is used to exhibit various functions in the DF: it is added to a drilling

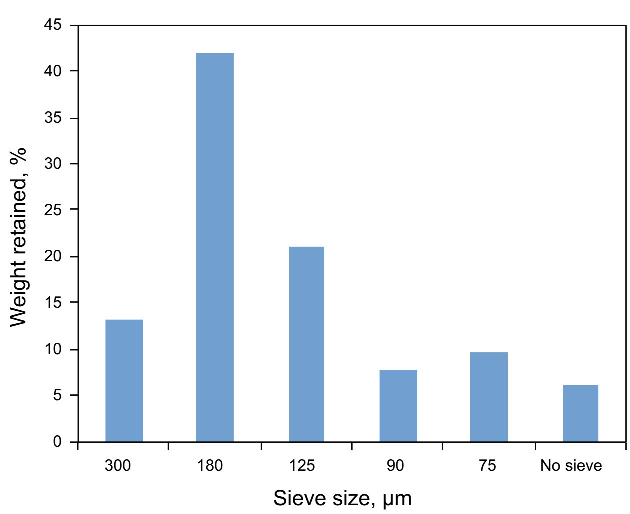

Fig. 1 Normal distribution curve of the grass sample on various sieves

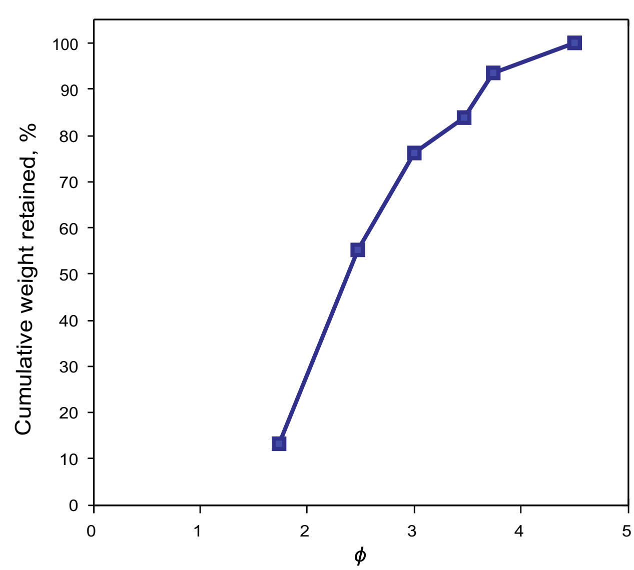

Fig. 2 Frequency distribution curve of the grass sample (where ϕ is a dimensionless unit of the sieve sizes and is defined as $\phi = -\log_{10}d/\log_{10}2$

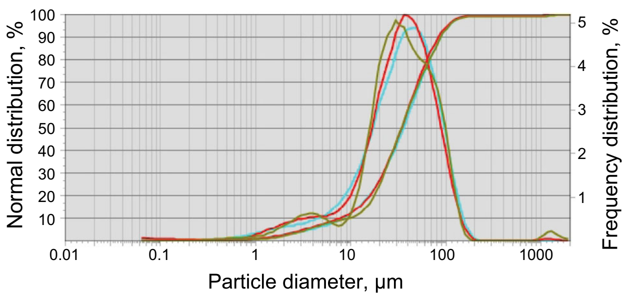

Fig. 3 Particle size distribution of the finest grass fraction obtained using a particle size analyzer

Table 2 XRF analysis of grass

Element	Net normal weight, %
Calcium (Ca)	53.80
Potassium (K)	19.83
Chlorine (Cl)	15.54
Sulfur (S)	3.89
Silicon (Si)	3.13
Iron (Fe)	2.46
Phosphorous (P)	1.24
Manganese (Mn)	0.12

fluid to change density, ionic strength, charges, etc. that are needed for special functions of DF such as drill-bit cooling, bit cleaning, effective cuttings removal to surface, downhole pressure control, and shale stabilization. Similarly, the use of silicate drilling fluids offers the advantages of prevention of bit-balling, differential sticking, and lost circulation and, in addition, promotes corrosion inhibition. Phosphoric acid is used to reduce the pH of the drilling fluid which is done conventionally.

The intention of mentioning the said compounds is to highlight the principal elements (K, Ca, Cl, Si, etc.). It is expected that the presence of these elements may contribute to mimic the performance of their toxic counterparts in an eco-friendly manner as grass is organic in nature. Moreover, readers may argue that grass is composed of lignin which itself is structured with C, H, and O. A separate SEM–EDX study conducted revealed that grass comprises of 95 % of these elements combined, and hence, were ignored from analysis (as an option present within the software of the XRF machine) as the authors focused on the applicability of other elements (as discussed in the previous paragraph) found in the grass sample.

4.3 Composition of the developed drilling fluid systems

Table 3 shows the compositions of the DF systems developed. The use of grass as an additive for DFs is unknown to the industry. Hence, the formulations are kept simple with water, bentonite, and grass (in varying concentrations) to study the effect of grass in the DF. The bentonite formulation was kept under agitation for 24 h so as to achieve a homogenized suspension and allow bentonite to swell to its capacity. Also, it is noteworthy to mention that the viscosities and yield point obtained can be normalized using barite.

5 Results and discussion

5.1 Rheological properties of bentonite drilling fluids added with 300-µm grass particles

This section presented here shows the rheological profile of grass of a particle size of 300 µm. All DF systems show good dial readings with values increasing progressively from 3 rpm dial speed to 600 rpm. Figure 4a shows the consistency curves for all concentrations of grass. All these curves are in good agreement with the Bingham plastic model, and it is observed that the shear stress increased with the concentration of grass at a given shear rate. It is seen that the apparent viscosity gradually increased as the concentration of grass increased in the DF system, whereas the PV remained constant after the initial concentration of 0.25 ppb (Fig. 4b). This is practically good as a DF with higher PV increases the ECD, surge, and swab pressures and also reduces the ROP with chances of differential sticking. Figure 4c indicates that the yield point remained constant at lower concentrations, and increased gradually as the concentration of grass increased in the DF system. It is a known fact that a high yield point fluid has more significance as it indicates better cutting carrying capacity. As observed in Fig. 4d, the initial and final gel strengths are found to be increasing gradually, which indicates better suspension of cuttings in the DF. Moreover, it has been observed from experience that high gel strength values are not sought as this requires high pumping pressure once drilling is resumed after a period of shut down.

5.2 Filtration properties of bentonite drilling fluid added with 300-µm grass particles

Filtration is an important phenomenon seen in the wellbore due to pressure exerted by the hydrostatic column of the drilling fluid. Due to a pressure differential, a mud cake or filter cake with very low permeability is formed on the walls of the borehole which acts as a barrier between the formation and the drilled bore. The amount of filtrate loss to the formation is also essential as a DF with greater filtrate loss will exhibit higher density due to reduction in the

Table 3 DF types used in this research

Sample	Size of grass particles, μm	Additives	Amount	Fluid weight, ppg
Sample 1	–	Water + bentonite	Water: 350 mL; bentonite: 22.5 g	8.6
Sample 2	300	Water + bentonite + grass	Water: 350 mL; bentonite: 22.5 g; grass: 0.25, 0.50, 0.75, or 1.0 g	8.6
Sample 3	90	Water + bentonite + grass	Water: 350 mL; bentonite: 22.5 g; grass: 0.25, 0.50, 0.75, or 1.0 g	8.6
Sample 4	35	Water + bentonite + grass	Water: 350 mL; bentonite: 22.5 g; grass: 0.25, 0.50, 0.75, or 1.0 g	8.6

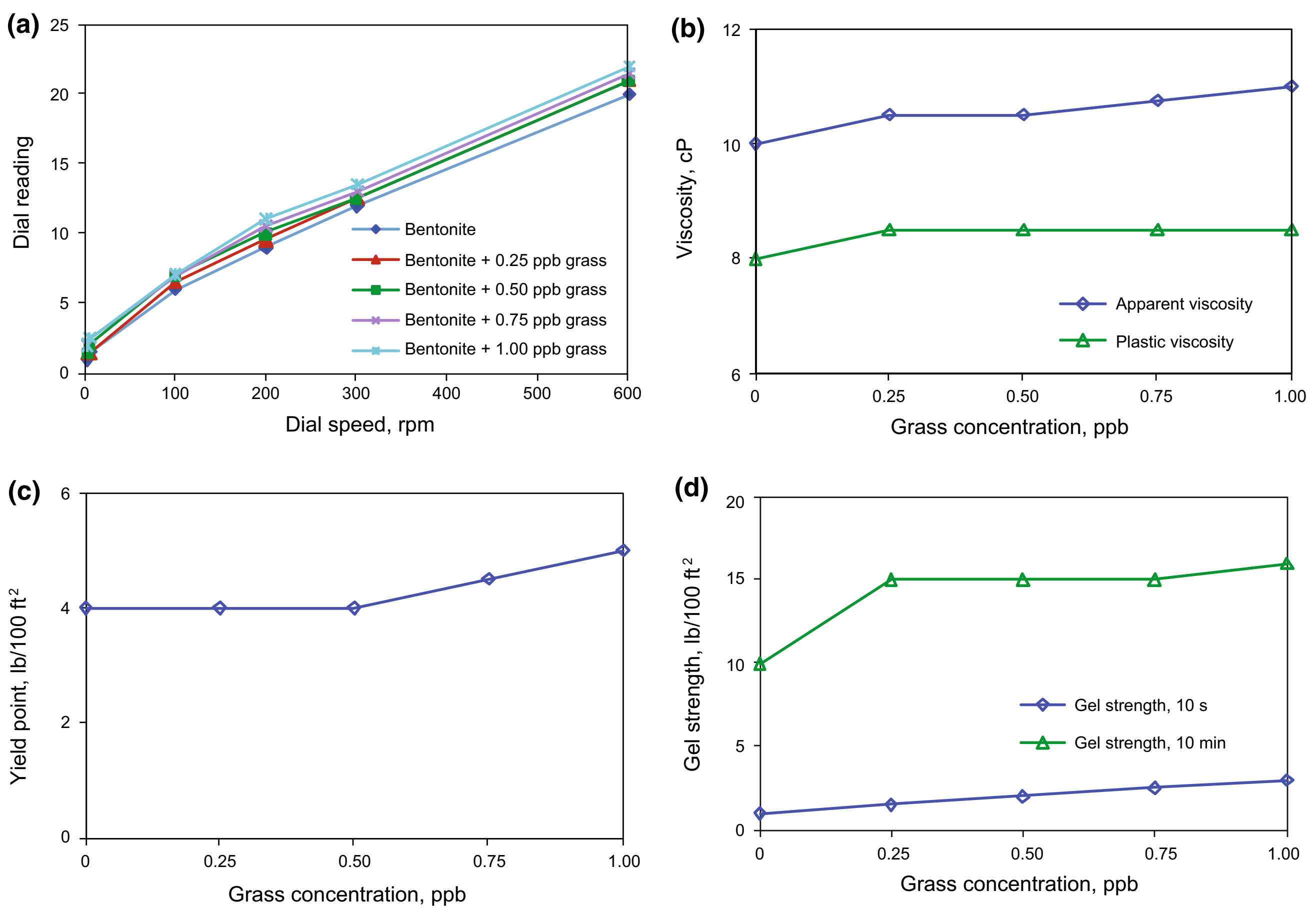

Fig. 4 Plot of rheological parameters for drilling fluids formulated with grass particles of 300 μm

water content of the fluid. Moreover, this creates a zone of damage near the well bore region and is one of the factors considered for formation damage. Figure 5 shows the trend of the filtrate loss of the drilling fluid formulated using the 300-μm sample. The filtration properties exhibit a decrease in the filtrate loss to a maximum of 24.7 % as the concentration of grass increased in the drilling fluid. This ensures that a firm filter cake is formed and a lesser amount of filtrate invades the formation which is an important property of a drilling fluid.

5.3 Selection of optimal concentration for 300-μm grass particles

Figure 6 shows all rheological properties and filtration characteristics for drilling fluids formulated with 300-μm grass particles. This is done in order to find out a concentration where all rheological properties (PV, YP, and GS) as well as the filtration characteristics are reasonable. It is concluded from Fig. 6 that the optimal concentration of grass particles of 300 μm is 0.75 ppb.

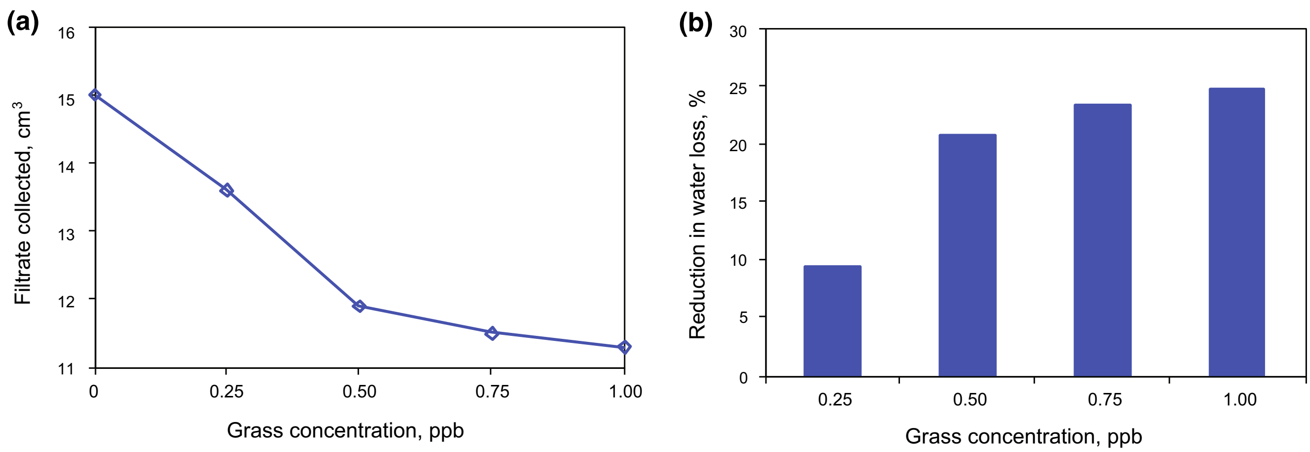

Fig. 5 Filtration characteristics of drilling fluids formulated with grass particles of 300 µm

5.4 Rheological properties of bentonite drilling fluid added with 90-µm grass particles

This section here shows the rheological profiles of drilling fluids containing grass particles of 90 µm. All DF systems show good dial readings with values increasing progressively from 3 rpm dial speed to 600 rpm. Again it is seen in Fig. 7a that the consistency curves confirm to the Bingham plastic model where shear stresses increased as a function of the shear rate. As observed in Fig. 7b, the viscosities increased as the concentration of grass increased in the DF system. As stated earlier, a DF with higher PV increases the ECD, surge, and swab pressures, and also reduces the ROP with chances of differential sticking. From Fig. 7c, it is clearly evident that the grass particles (at this particular particle size) did not contribute enough to impart high yield points as this defines the cutting carrying ability of the DF. The gel strengths (Fig. 7d) are found to be increasing progressively which indicates that this drilling fluid had good cuttings suspension quality.

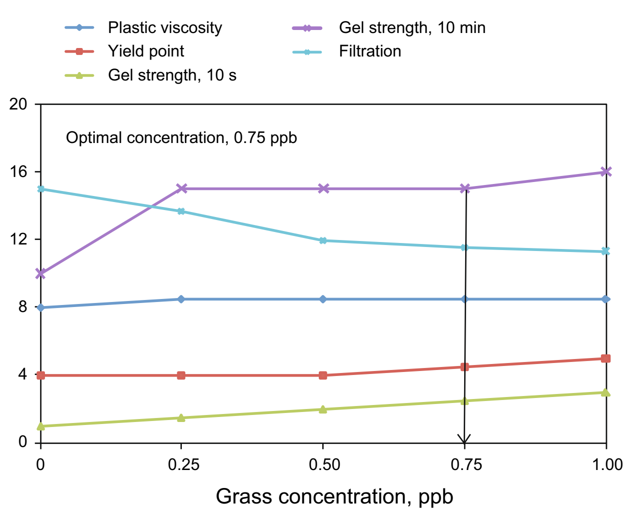

Fig. 6 Selecting the optimal concentration for 300-µm grass particles

5.5 Filtration properties of bentonite drilling fluid added with 90-µm grass particles

Figure 8 shows filtration characteristics of the drilling fluid formulated using 90-µm grass particles. Figure 8a illustrates that as the grass particles were added to the bentonite DF system, the filtration characteristics of the drilling fluid improved as evident. The reduction in water loss observed was 23.3 % at a concentration of 1.0 ppb (Fig. 8b).

5.6 Selection of optimal concentration for 90-µm grass particles

Figure 9 shows all rheological properties and filtration characteristics of the bentonite drilling fluid containing 90-µm grass particles. The optimal concentration of grass particles was selected where all rheological properties (PV, YP, and GS) as well as the filtration characteristics are rational. It is concluded that the optimal concentration of grass particles of 90 µm is 1.0 ppb (Fig. 9).

5.7 Rheological properties of bentonite drilling fluid added with 35-µm grass particles

This section here presents the rheological profile of bentonite drilling fluid containing grass particles of 35 µm. All DF systems show good dial readings with values increasing gradually from 3 rpm dial speed to 600 rpm. Figure 10a shows the consistency curves for all concentrations of grass. All these curves are in good agreement with the Bingham plastic model, and it is observed that the shear stress increased with the concentration of grass at a given

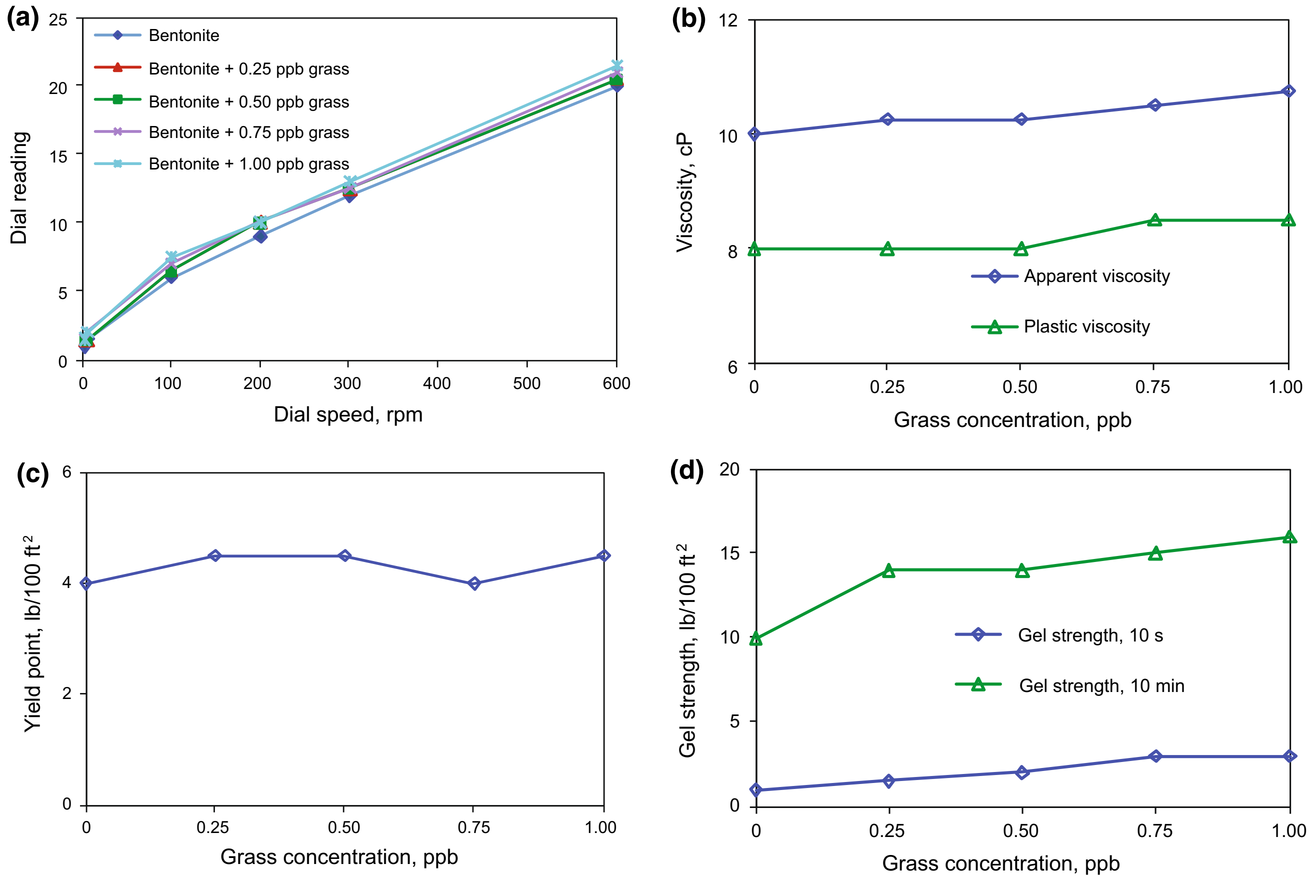

Fig. 7 Plot of rheological parameters for drilling fluids formulated with grass particles of 90 μm

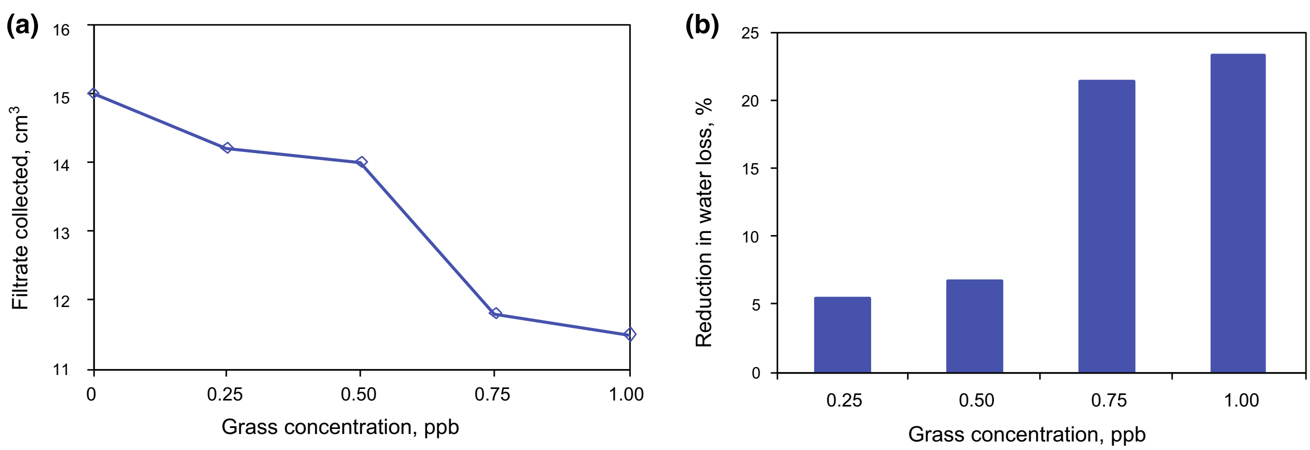

Fig. 8 Filtration characteristics of drilling fluids formulated with grass particles of 90 μm

shear rate. It is seen from Fig. 10b, c that the viscosities and the yield point gradually increased as the concentration of grass increased in the DF system. A DF with higher PV increases the ECD, surge, and swab pressures and also reduces the ROP with chances of differential sticking. It is known that a high yield point fluid has more practical significance as it indicates better cutting carrying capacity. As observed in Fig. 10d, the initial and final gel strengths are found to be increasing gradually, which indicates better suspension of cuttings in the DF.

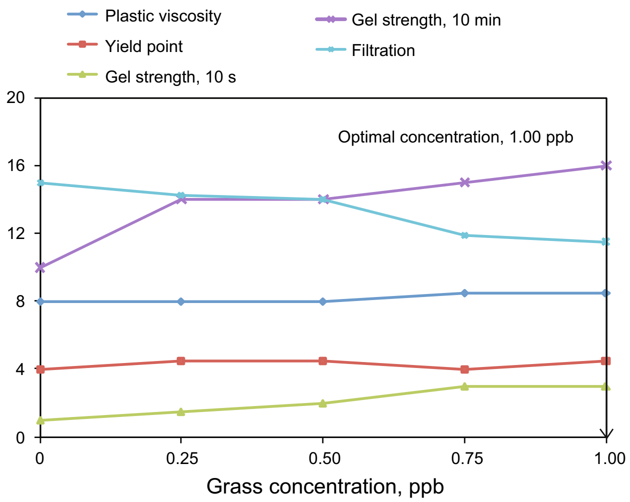

Fig. 9 Selecting the optimal concentration for 90-μm grass particles

5.8 Filtration properties of bentonite drilling fluids added with 35-μm grass particles

Fluid loss is a common occurrence in drilling operations. DFs are designed to seal porous formations intentionally while drilling, by the creation of a mud cake. However, some part of the fluid is lost through the mud cake, and thus, fluid loss control additives are required. In this section, the fluid loss characteristics of grass drilling fluids are depicted. The filtration properties for the drilling fluid added with different concentrations of grass are shown in Fig. 11. It is seen in Fig. 11a that as the grass was introduced into the drilling fluid, filtration was controlled as evident by the decreasing trend. A reduction in water loss of 19.3 % was observed at a concentration of 1.0 ppb which is the least at this particle size (35 μm).

5.9 Selection of optimal concentration for 35-μm grass particles

Figure 12 shows all rheological properties and filtration characteristics for the drilling fluids formulated with 35-μm grass particles. The optimal value of grass concentration is selected where all rheological properties (PV, GS, and GS) as well as the filtration characteristics are reasonable. It is concluded Fig. 12 that the optimal concentration of grass particles of 35 μm is 0.75 ppb. Here, 1.0 ppb is not selected as the optimal concentration as in previous cases because of the gel

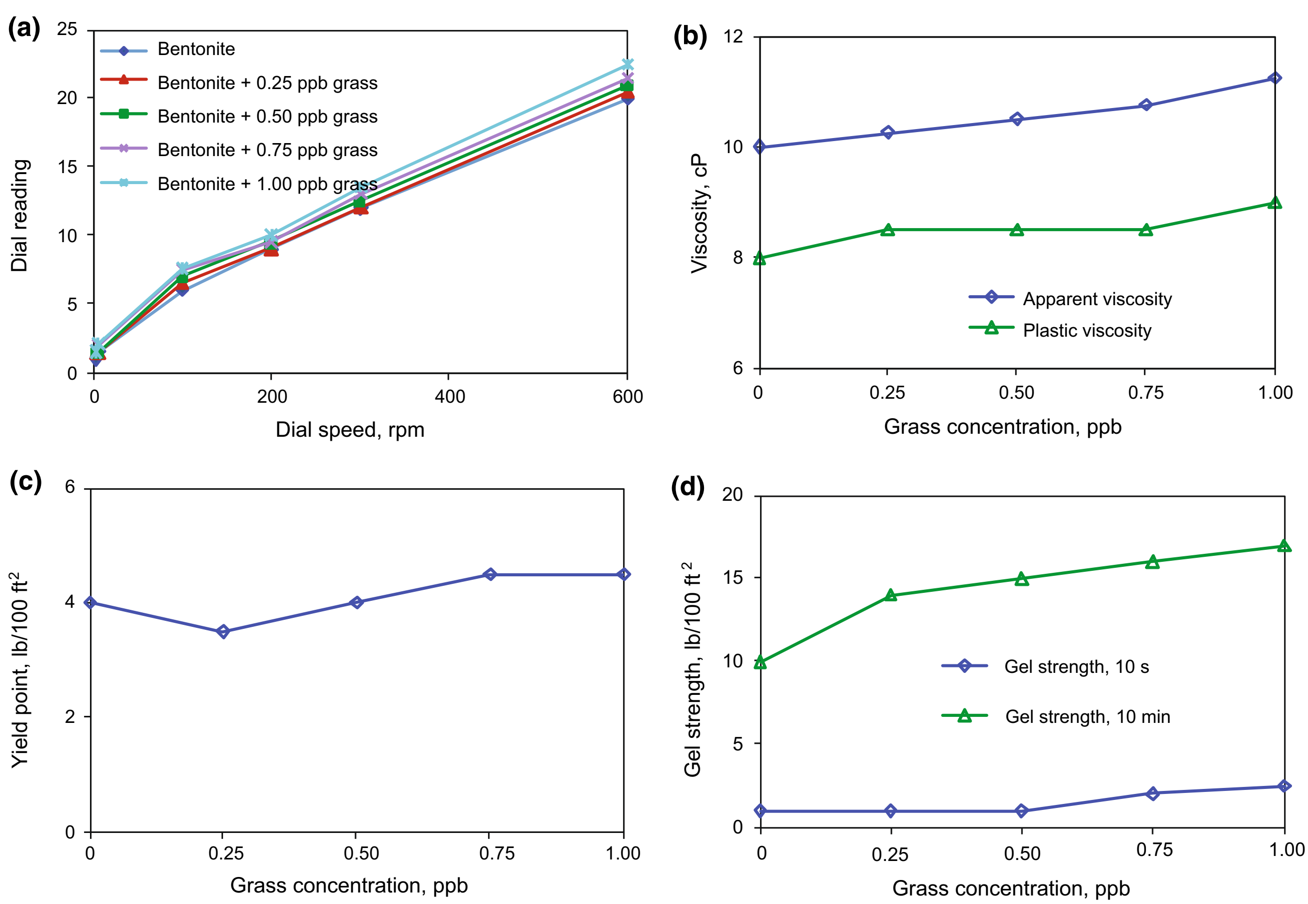

Fig. 10 Rheological parameters for drilling fluids formulated with grass particles of 35 μm

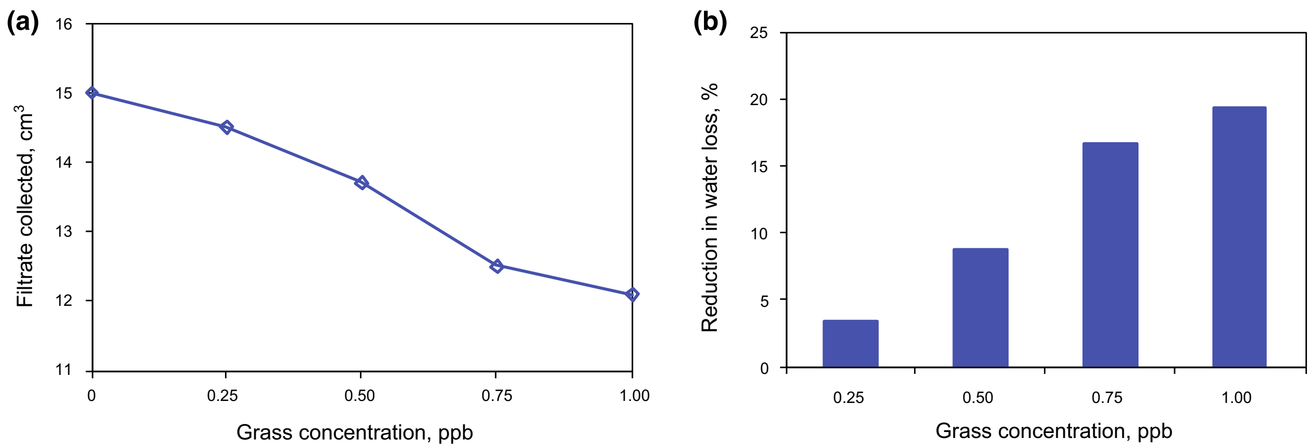

Fig. 11 Filtration characteristics of drilling fluids formulated with grass of 35 μm

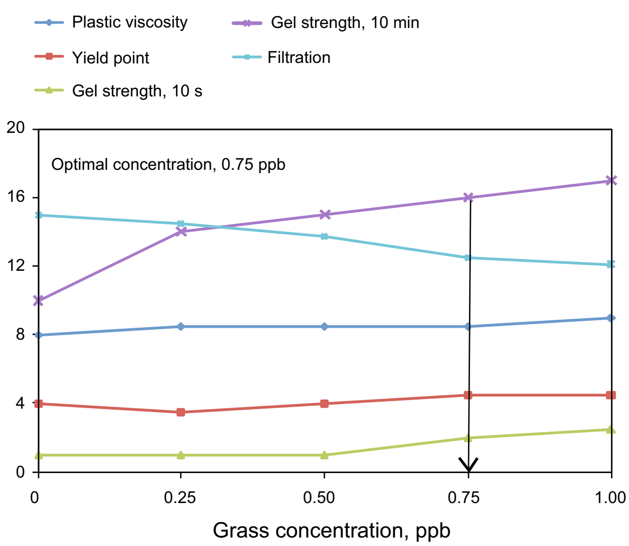

Fig. 12 Selecting the optimal concentration for 35-μm grass particles

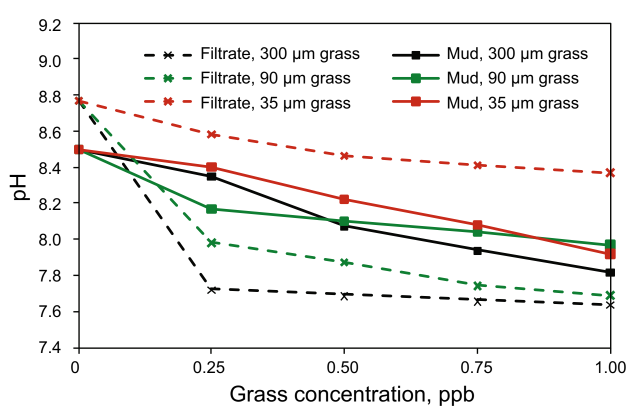

Fig. 13 Effect of the concentration of grass particles on pH of bentonite drilling fluids

strength which is significantly high at the highest concentration as this would require high pump pressures for recirculation in case of pump shut down during fishing operations.

5.10 Effect of grass on the pH of the drilling fluid

pH is a measure of the hydrogen ion concentration of a solution. Figure 13 illustrates the trend of pH followed by the drilling fluid with added grass particles. It can be inferred from the plot that as the grass particles were added to the bentonite drilling fluid, the pH of the filtrate, as well as the drilling fluid decreased (solution tends to become acidic). It is well-known that the drilling fluid gets contaminated through its various trips into the borehole which either increases or decreases its pH. Owing to the experiments conducted, we proposed to use grass as a greener alterative to lower the pH of a contaminated drilling fluid whose pH has been raised to an unacceptable level.

Potassium hydroxide, sodium hydroxide, calcium hydroxide, and magnesium hydroxide are commonly used as alkalinity and acidity control agents in DFs. These chemicals are declared as very hazardous in case of skin contact, eye contact, ingestion, and inhalation. An alternative solution would be to use grass as it modifies the pH of the drilling fluid and is environmentally friendly imparting no ill effects on the health of personnel who are daily involved in this trade.

6 Comparison of the rheology of grass drilling fluids with different water-based drilling fluids

A comparison is made between the existing water-based DF systems and the newly formulated grass drilling fluid using data from Amoco Production Company available in an open source web link (Drilling Fluids Manual, Amoco Production Company. Accessed on February 24, 2015 at 8:15 PM. http://www.academia.edu/6348534/Drilling_Fluids_Manual). Table 4 is prepared based on the data available on different water-based DF types to compare the proposed grass drilling fluid. The parameters such as PV,

Table 4 Comparison between proposed grass drilling fluid and various water-based drilling fluid systems

Drilling fluid type	Density, ppg	Plastic viscosity, cP	Yield point, lb/100 ft^2	Gel strength, lb/100 ft^2		Filtrate, cm^3/30 min	Cost
				10 s	10 min		
Lignite/lignosulfonate muds* (deflocculated)	9	8–12	6–10	2–4	4–10	8–12	Moderate
Lime muds*	10	15–18	6–10	0–2	0–4	6–12	Low
Lime muds* (deflocculated)	9	9–12	2–20	0–5	1–20	8–12	Low
Gypsum muds*	9	12–15	6–10	2–4	8–12	8–12	Moderate
Brackish-water muds*	9	16	10–18	2–4	5–10	6–10	Moderate
KCl-polymer muds*	9–10	12–25	10–20	6–8	8–20	10–12	Moderate
KOH-lignite muds*	9	12–24	9–12	2–4	4–8	10–12	Moderate
KOH-lime muds*	9	10–12	8–12	4–6	6–10	6–9	Moderate
New grass mud	8.6	8–9	3.5–5	1–3	10–78	11–14.5	N/A

* Source-Amoco Production Company

N/A not available

YP, GS, and the filtrate loss are included for the comparison. Table 4 shows that different DF systems have different properties and show a clear contrast. The grass drilling fluid seems quite comparable with these drilling fluids. All drilling fluids are formulated using additives which include a viscosifier, a weighting agent, a filtration control agent, and an alkalinity control agent, whereas the proposed system comprises only a viscosifier and powdered grass. It is expected that the cost of formulating grass drilling fluid is very low solely based on experience as well as owing to the abundance of the source material, grass. However, no formal cost analysis is conducted.

7 Conclusions and recommendation

Grass was used as an additive for the formulation of an environmentally friendly DF with different particle sizes and concentrations. The results obtained show that grass added to the bentonite DF (all concentrations at various particle sizes) improved the rheological properties such as apparent and plastic viscosities and gel strength. The filtration characteristics of the bentonite drilling fluid also enhanced because lower filtration losses were observed for all the samples. Tests carried out on the pH indicated that the addition of grass decreased the pH of the drilling fluid. The obtained results can be summarized as below:

(1) Tests carried out on drilling fluids formulated using 300-μm grass particles exhibited a control in filtration loss of about 25 %. Significant increases in the viscosities, yield point, and gel strengths were also observed. The optimal concentration of grass particles was 0.75 ppb in the bentonite drilling fluid (at 300 μm).

(2) The formulation containing 90-μm grass particles revealed a 23 % decrease in the filtration loss. Increases in the viscosities, yield point, and gel strengths were also significant. An optimal concentration of 1 ppb grass particles was suggested at this particle size.

(3) Formulations containing fine-sized grass particles, i.e., 35 μm, helped decrease the filtration loss to 19 %. The viscosities, yield point, and gel strengths also show some increments. The optimal concentration witnessed was at 0.75 ppb of grass material.

Grass is proposed as a rheology modifier, filtration control agent as well as an alkalinity control agent for a DF. We further recommend carrying out investigations with this additive at elevated temperatures to analyze its performance so that a strong decision can be made in favor of the proposed grass which can be a better choice to replace the current toxic chemicals. Also, it is highly encouraged to develop a cost analysis model so as to study the applicability of grass as an additive for a DF system.

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