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EXPERIMENTAL STUDY OF NON-DAMAGING DRILLING FLUID USING BIODEGRADABLE REAGENTS FOR SHALE STABILITY

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ABSTRACT

For hydrocarbon production drilling a borehole is a very important process in the petroleum industry. Drilling fluid is used for an effective drilling operation to produce the crude oil. Bentonite and Barite is used in a conventional drilling fluid which is a disadvantage as they react with shale and cause formation damage. This can lead to reduce in productivity and the economic value. Therefore, to prevent it, a non-damaging drilling fluid (NDDF) is synthesized using biodegradable reagents to avoid the formation damage. A NDDF fluid of psyllium husk and turmeric is prepared to counter the problems faced by conventional drilling fluid. A rheological property as well as the shale stability test has been investigated for the prepared unconventional fluid/ NDDF. It was observed that the selected NDDF fluid prepared using psyllium husk and turmeric showed good enhancement in rheology. Due to the presence of psyllium husk, the filtrate loss is observed to be reduced from the shale stability test. The shale samples have been obtained from Assam-Arakan basin. This work is mainly focused on using minimal number of biodegradable reagents such as turmeric and psyllium husk. Therefore, it can be used in unconsolidated formations to prevent it from the formation damage and have a potential to be used in an economical way due to the less cost and easily available of the above-mentioned reagents.

Keywords: Non-damaging drilling fluid (NDDF); Psyllium husk; Rheological properties; Shale stability; Turmeric.

1. INTRODUCTION

The drilling fluid or the drilling fluid is a well-made/ prepared single component that's is kept in contact with wellbore until and after the drilling operation. Some amount of specially prepared fluid is pumper using some fluid pumps from the surface and exists at the bit and it come back through the annulus to the surface for drill cutting removal. Some basic functions of the drilling fluid are a) the drill cutting is removed by bring it to the surface b) to balance the formation pressure c) it supports the well bore until casing is done d) helps in lubrication the drill string [1-4]. The types of drilling fluids are a) freshwater drilling system b) saltwater based drilling system c) oil or synthetic based drilling fluid. Drilling in offshore and onshore more than 70% are shale formation and 90% of the times wellbore instability take place [5-9]. These shale formations contains more amount of organic matter similar to source rocks and developed fracture networks unlike conventional formations. According to research mostly OBM performed much better when drilled using WBM but its not the solution for the problems occurring while drilling. The main reason for well bore instability is that the conventional drilling (bentonite and barite) react with the shale formation therefore more swelling and spalling take place. Mechanism for formation damage due to drilling fluid are a) formation plugging due to bentonite and barite b)hydration of clay envelop around the pay zone c) chemical reaction between formation fluid and fluid. Therefore to over this issue Non damaging drilling fluid is used. It is seen that NDDF has reduced the formation damage and react comparatively less with shale. NDDF is mainly used for the increment of production by reducing formation damage. It is said that when the formation damage is reduced there is more productivity [11-14].

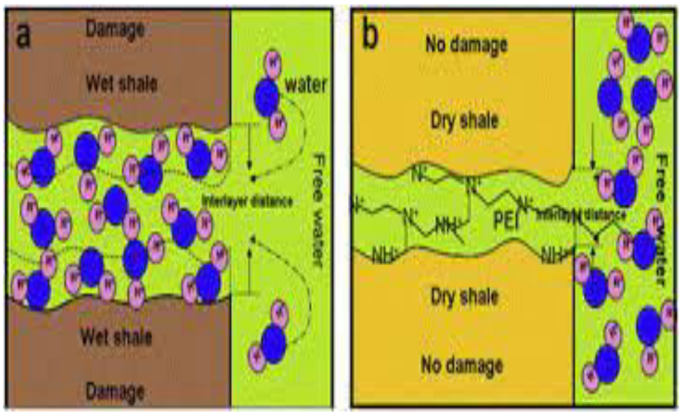

Fig1: Reaction of water based drilling fluid in shale ([16])

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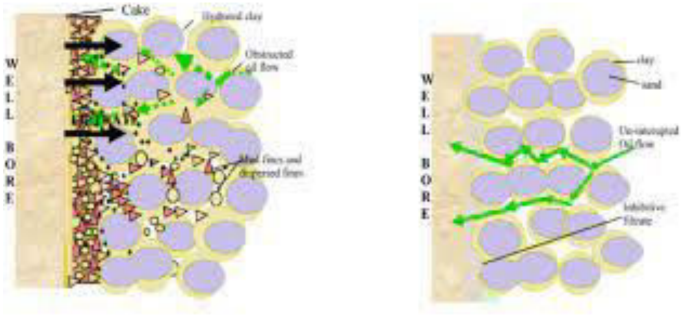

(a) (b)

Fig2 (a): Reaction of conventional fluid in shale **2(b):** Reaction of NDDF in shale [20]

The NDDF fluid was firstly introduced in the Mehsana asset of ONGC, in North Cambay basin India [10]. In NDDF components like bentonite and barite are not used, minimal drilled fine solids, filtrate does not react with formation to form any precipitate. Fine solid in conventional drilling fluid enter the formation and blocks the oil to come out, but NDDF has has no such fine particles. The fluid filtrate swells the clay envelops thereby obstructing the oil flow. [15]

In this work we are mainly focusing on the synthesis and development of NON damaging drilling fluid using less amount of biodegradable additives like turmeric, psyllium husk, $CaCO_3$ and CMC. The determination of the rheological properties are done and examined using various equipment's for different composition of CMC as well as different composition of psyllium husk. Different NDDF fluid have been prepared using various additives but the main goal is to reduce the number of additives used and prepare a better and less reactive NDDF fluid.

2. EXPERIMENTAL SECTION

2.1. Materials

Only four additives were used in this work and they are psyllium husk, turmeric, carboxy methyl cellulose (CMC), calcium carbonate ($CaCO_3$). In this work, psyllium husk is mainly used for increase of gel strength and also consider it for filtration agent. Turmeric is mainly used as they act as an anticorrosive agent as well as they act as good adsorbent and reduce the friction. The corrosion inhibition result of turmeric is attributed to the surface assimilation of phenolic resin constituents over the metal surface. $CaCO_3$ is mainly used because they bridge a pore throat on the formation for external filtrate cake. They are used to induce higher amount of specific gravity instead of barite. CMC is used as a viscosifier and additionally acts as a water loss preventive.

2.2. Experimental Set-Up

Fig3: Hand crank viscometer

Fig4: Marsh funnel

Fig5: pH meter

Fig6: Fluid balance

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Fig 7: Remi stirrer

The fluid is prepared using the Remi stirrer as shown in the figure 7. Distilled water is used throughout the experiment for preparation of fluid. Organic turmeric, fine $CaCO_3$, psyllium husk and CMC is mixed for certain period of time using Remi stirrer. The specific gravity of the prepared fluid is determined using fluid balance instrument as shown in the figure 6. The apparent viscosity, yield point, plastic viscosity is determined using the hand crank viscometer as shown in the figure 1. The marsh funnel is used to find the effective viscosity as shown in the fig 4. The pH meter as shown in the fig 5 is used to find the PH of the prepared fluid.

2.3. Experimental Procedure

A predetermined concentration of the required additives where taken. The required amount was weighed and were added or mixed to 1500ml of distilled water. This mixture was stirrer to a certain period of time using the Remi stirrer [fig 7]. This process helps to smoothen the drilling fluid thereby making uniform properties throughout the fluid. Firstly, the density of the prepared fluid is measured using fluid balance [fig 6]. Certain amount of fluid is poured into the equipment and the equipment is balanced until the bubble in centralized. The density is noted in ppg, specific gravity, lb/ft^3, psi/1000ft. The apparent viscosity, plastic viscosity, yield point and gel strength is measure using the hand crank viscometer [fig 5]. The viscometer gives us the shear stress values which are later converted. The hand crank viscometer is used to measure the shear stress at 600rpm and 300rpm. Using these shear stress the required properties are determined using below formulas eq 1, eq 2 and eq 3:

Plastic viscosity (centi poise) = 600rpm-300rpm (1)

Apparent viscosity (cp) = 600rpm/2 (2)

Yield point ($lb/100ft^2$) = 300rpm – plastic viscosity (3)

The ratio of yield point and apparent viscosity is also determined using the below formula

Eq (4): [17]

Ratio yp/ap = yield point / apparent viscosity (4)

The hand crank is kept at 3rpm to determine the gel strength of the prepared drilling fluid. The gel strength is noted for 10sec at 3rpm and the fluid is kept idle for 10mins and again the same process is repeated. First observed is the initial gel strength and after 10mins the observed is the final gel strength [18]. The PH of drilling fluid with different concentration is determined using the PH meter. The PH rod is dipped into the drilling fluid and the PH is noted. To find the effective viscosity, marsh funnel equipment is used [fig 4]. The prepared drilling fluid is filled into the marsh funnel upto the marked point. The drilling fluid is let freely to pour into a beaker upto 950ml and the timing is noted. Two trials are done and the average of both the time is taken into consideration. Using the determined time we use the below equation to find the effective viscosity of the drilling fluid eq 5 [17]:

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Effective viscosity: sp.gr t-25 (5)

Where sp.gr = the density of the drilling fluid, t = time taken by the fluid to flow out of marsh funnel.

The result or the observation of all the tests is compared with each other and two best concentrations with best rheological properties are selected and the shale stability test is performed.

In shale stability test, the shale rocks are taken and crushed or powdered into fine particles using hammer. These powdered shale particles are dried in the oven at 67℃ for 2 hours. After drying, the shale sample are weighed and later filled into the vial tubes of 14ml. the shale sample is filled upto 7ml and the NDDF prepared is filled from 7ml to 14ml. As two best NDDF was taken, two vial tubes the filled the same way. The vial tubes were left to rest for 24 hours and every 2 hour the reading was observed. This is done to determine the reaction with shale, whether it was absorbing fluid and expanding. Later after 24 hour the wet shale is take weighed and again it is dried in the oven for 2 hours at 67°C. The dried sample is again weighed. The spalling and swelling if determined using below eq 6 and eq 7 [20]:

$$\text{Swelling (\%)} = \frac{\text{wt of wet rock (g)-wt if dried rock after immersion (g)}}{\text{Wt of dried rock after immersion (g)}} \quad (6)$$

$$\text{Spalling (\%)} = \frac{\text{initial dry weight (g)} - \text{wt of dried rock after immersion (g)}}{\text{Wt of dried rock after immersion (g)}} \quad (7)$$

3. RESULTS AND DISCUSSION

In this work, the non damaging drilling fluid comprises of mainly just four additives which are: psyllium husk, turmeric, CaCo3, CMC. These additives are added one by one with distilled water to formulate the NDDF. Each additive is added to improve or enhance the properties of the prepared drilling fluid. Therefore the concentration of each additive is tested the best or optimum concentration for each additive is taken.

3.1 NDDF Fluid Using Different Concentration of CMC

These additives are added one by one with distilled water to formulate the NDDF. Each additive is added to improve or enhance the properties of the prepared drilling fluid. Therefore the concentration of each additive is tested the best or optimum concentration for each additive is taken. 1500L of distilled water is taken.

Three NDDF sample is made or prepared using a) 7.5g of turmeric + 25g of psyllium husk+ 3.15g of $CaCO_3$ + 4.8 g of CMC.

b) 7.5g of turmeric + 25g of psyllium husk + 3.15g of $CaCO_3$ + 4.9 g of CMC

c) 7.5g of turmeric + 25g of psyllium husk + 3.15g of $CaCO_3$ + 5g of CMC

Three fluid samples were prepared using these concentrations and the rheological properties of these fluid samples are observed. For Fluid (a) it was observed that the plastic viscosity is 72cp and apparent viscosity is 93.5cp and the effective viscosity is 173cp. Fluid (b) it was observed that plastic viscosity is 45cp and apparent viscosity is 72.5cp and effective viscosity is 119cp. Fluid (c) it was observed that plastic viscosity is 31cp apparent viscosity is 54.5cp and effective viscosity is 69cp.

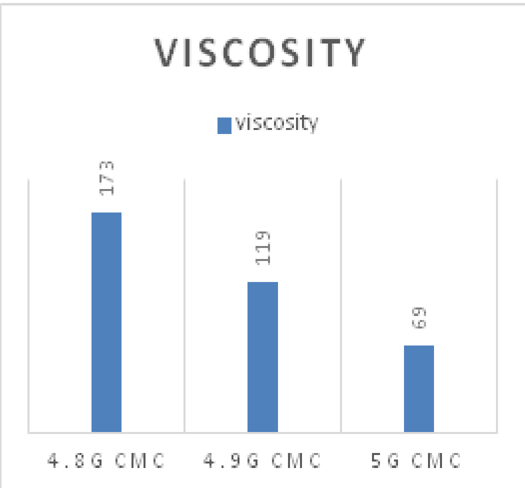

Fig 8: Viscosity for different conc of cmc

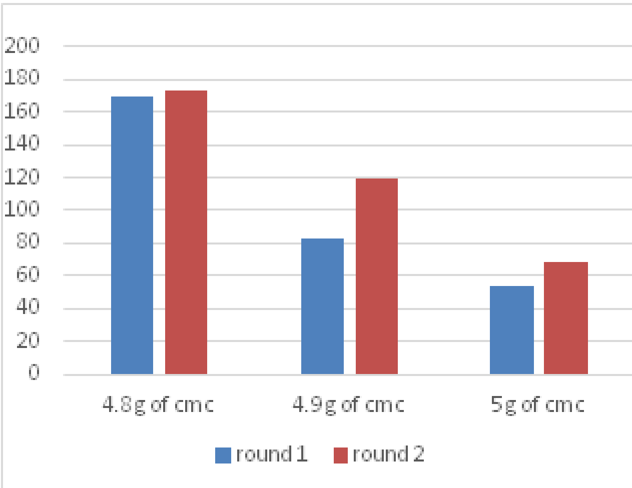

Fig 9: Two rounds for each NDDF fluids

As we can see in the figure 8, the concentration of CMC is different for three different fluid is varying. The viscosity of fluid with concentration of 5g CMC is comparatively less compared to other concentration of CMC. For each concentration of fluid two rounds is done to find the rheological properties. And the values from the second round is taken in consideration. As 5g of CMC gives us better effective viscosity it is taken into consideration

3.2. Different Concentration of Psyllium Husk

As 5g of CMC is taken into consideration now we prepare and observe the fluid for different concentration of psyllium husk. The following are the concentration used to prepared the fluid sample:

a) 7.5g of turmeric + **25g** of psyllium husk + 3.15g of CaCo3 + 5g of CMC

b) 7.5g of turmeric + **15g** of psyllium husk + 3.15g of CaCo3 + 5g of CMC

c) 7.5g of turmeric + **5g** of psyllium husk + 3.15g of CaCo3 + 5g of CMC

d) 7.5g of turmeric + **1g** of psyllium husk + 3.15g of CaCo3 + 5g of CMC

The rheological property of fluid sample of these concentration is observed and the best concentration of fluid is taken into consideration.

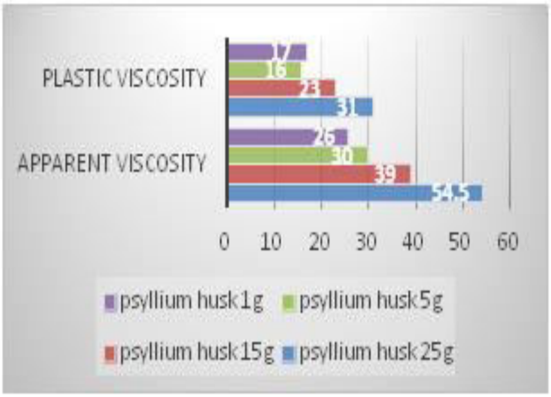

Fig 10: Viscosity of various conc of psyllium husk

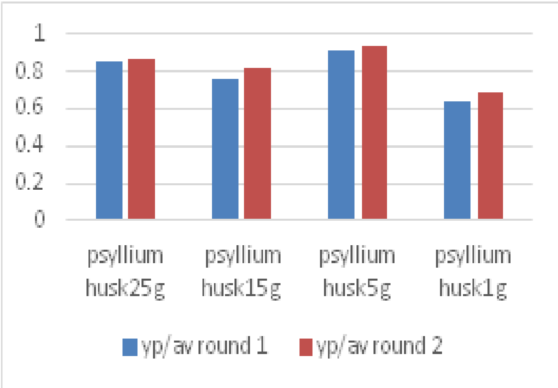

Fig 11: YP/AV ratio of diff conc. of psyllium husk

As seen in the figure 10, the plastic viscosity and apparent viscosity is determined for various concentration of psyllium husk. The values are observed for two rounds of the fluid of each concentration. It is observed that the apparent viscosity and plastic viscosity of the fluid is decreasing as the concentration of psyllium husk decreases. In fig 11, the yp/av ratio is considered every fluid prepared with different conc of psyllium husk. Higher YP/PV ratio is desirable for greater shear-thinning because it can reduce the pumping pressure in drill pipe and increase the cutting carrying capacity in the annulus region [5]. The yp/av ratio of 5g of psyllium husk is closer to 1 therefore is taken into consideration

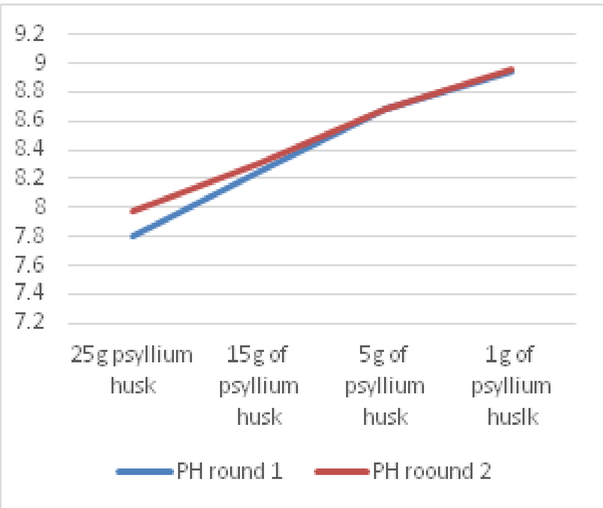

Fig 12: pH of different conc. of psyllium husk

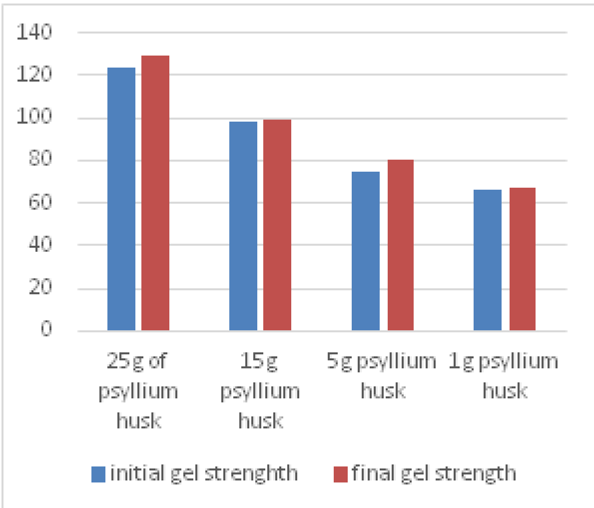

Fig 13: Initial and final gel strength of psyllium husk

Fig 12 show us the PH of fluid different concentration of psyllium husk. It is observed that as the psyllium husk concentration is decreased there is a good rise in the pH of the fluid. The PH of fluid with psyllium husk of 5g and 1g has 8.69 and 8.96 which is a good pH thereby chance of corrosion is less. Fig 13 shows us the initial and final gel strength of fluid with different concentration of psyllium husk. It is observed that as the concentration of psyllium husk is decreased there is drastic change or decrease in the gel strength of the prepared fluid. We can observed the gel strength of 25g is psyllium husk is 129 lb/100sqft, 15g of psyllium husk is 99 lb/100sqft, 5g of psyllium husk is 80 lb/100sqft and 1g of psyllium husk is 67lb/100sqft. It is observed that 1g is psyllium husk is providing a better gel strength that other composition of psyllium husk. As the pH and gel strength is optimum, fluid of 5g and 1g psyllium husk is taken into consideration for shale stability test.

3.4. Shale Stability Measurement

Shale swelling or spalling are some main issues while drilling in shale formation. Drilling fluid consisting of bentonite and barite react with the shale formation and cause formation damage, stuck pipe, collapse [19,20]. Therefore NDDF mud is being used in shale formation as they are less reactive with shale and the swelling and spalling percentage of the fluid would be comparatively less compared to conventional drilling fluid. The formulated NDDF fluid of 5g of psyllium husk and 1g of psyllium husk is prepared under 400ml of distilled water with following measurement = > fluid 1: 0.84g of $CaCo_3$ + 1.33g of CMC + 2g of turmeric + 1.33g of psyllium husk + 400ml of distilled water.

Fluid 2: 0.84g of $CaCo_3$ + 1.33g of CMC + 2g of turmeric + 0.2g of psyllium husk + 400ml of distilled water.

Table 1: Shale stability reading for fluid 1 and fluid 2

Hour	Shale Volume (ml)	Fluid-1	Fluid-2
		Fluid Volume Level (mL)	Fluid Volume Level (mL)
0	7	14	14
2	7	14	13.9
4	7	14	13.9
6	7	14	13.9
8	7	14	13.9
10	7	14	13.9
12	7	14	13.9
14	7	14	13.9
16	7	14	13.9
18	7	14	13.9
20	7	14	13.9
22	7	14	13.9
24	7	14	13.9

During the test measurement it is observed that fluid 1 has not absorbed any NDDF mud or we can say no NDDF has reacted with the shale formation but in fluid 2, 0.1ml of fluid has been absorption with respect to 24 hours of time as shown in the table 1. We can conclude from this that with respect to 24hour time period the fluid 2 has reacted more than fluid 1. The swelling and spalling of both the shale sample is calculated using eq 6 and eq 7.

Table 2: Shale immersion test results

	Fluid-1	Fluid-2
Initial Dry Weight (g)	10.3	10.3
Wet Weight (g)	12	11.3
Dry Weight after Immersion (g)	10.1	10

From the Table 2 we can observe the initial weight of the shale sample, weight of shale sample after immersion (wet weight) and dry weight of shale sample after immersion. Using these data that we determine the swelling and spalling of the fluid 1 as well as fluid 2 using eq 6 and eq 7. Swelling percentage of fluid 1 is 18.80% and spalling percentage is 1.98%.

Swelling % of fluid 2 is 13% and spalling% of fluid 2 is 3%. From this we can observe that the swelling % of fluid 2 is less than that of fluid 1 and the spalling % of fluid 1 is less than that of fluid 2.

Overall it is clear that the prepared NDDF is more effective in shale formation. It gives us better swelling and spalling % than any previous NDDF mud prepared. The NDDF with 5g is considered better than 1g as we see in Table 1 there is no reduction od NDDF into shale sample. Which implies the NDDF did not react with the shale sample.

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4. CONCLUSION

The NDDF prepared using psyllium husk of two different concentration was formulated and compared which was tested for 24 hr to observe the reaction of the NDDF with shale formations. As the psyllium concentration is decreased, we observed an increase in pH value. Also, the gel strength was observed to be decreasing with decrease in psyllium husk concentration. From the shale stability test and static immersion test were carried out, it was observed that 5g psyllium husk NDDF is less reactive with shale compared to 1g psyllium husk NDDF. The rheological properties were determined and showed satisfactory result. The prepared NDDF consists of psyllium husk and CMC is used in this work. The swelling% and spalling% is comparatively less in the NDDF. The shale immersion test helped us know that 5g psyllium husk NDDF was less reactive in shale formation than 1g of psyllium husk. Thereby this reduce the risk of problems in the borehole like collapse and formation collapse. Therefore, the psyllium husk based NDDF show good potential to be used in pay zone and reduces the probability of problems during production due to better wellbore stability and helps in production of unconventional crude oils.

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