An Experimental Investigation on the Effect of Glycerol Added Psyllium Husk on Drilling Fluid Properties

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Abstract – *The conventional drilling fluids are proven to be effective in the current scenario, but it has certain limitation too due to the increasing challenges in the petroleum industry. A need exists for the strong, stable and customizable fluid which can be used in all areas of drilling. A sustainable and effective method of increasing the dispersibility of psyllium in the drilling fluid is tested and its effect on various rheological properties has been compared. Psyllium, an organic fiber, has the capability of forming a gel like product when mixed with water. It exhibits poor dispersibility in water. Glycerol is a waste product produced in large quantities by biodiesel industries. It is economical, easily available, and does not have any adverse effects on the environment. Efficient use of glycerol can be used to increase the dispersibility of psyllium in a solution and hence give direction to a combined effect. (T.E Gray & GBay,2005). Glycerol and psyllium dispersed together showed remarkable changes in the properties of drilling fluid. Comparative analysis of its effect on drilling fluids with different components was observed. The study was done for different amounts of glycerol and psyllium husk. The results obtained had shown a remarkable variation in terms of rheological properties for the glycerol added psyllium husk drilling mud than the conventional drilling fluid. Usage of the environment friendly products to produce drilling fluid with the requisite properties, has a check on environmental concerns and the probable imminent challenges.*

Key Words: **Drilling mud, Psyllium Husk, Glycerol, Rheological properties, Dispersibility**

1. INTRODUCTION

Drilling fluids are defined as any kind of liquid or gaseous fluids or mixtures of fluids and solids used in operations to drill boreholes into earth's surface. In this, generally the solids are used as solid suspensions, mixtures and emulsions of liquids, gases and solids. Generally liquid drilling fluids are known as drilling mud. Drilling fluids are mainly used to provide hydrostatic pressure to prevent formation fluids from entering the well bore, maintaining the drill bit clean and cool during the process of drilling, carrying out drill cuttings, and suspending the drill cuttings while drilling is paused and when the drill string is brought in and out of the hole. (Ariffin and Amir, 2011). Drilling mud determination is a component of the conduct of the formation to be drilled. (Bourgouyne, 1991; Lyons, 1996) Contrasted with different kinds of drilling mud, water-based mud has the upsides of higher shear diminishing, high evident yield quality, good bit hydraulics and reduced circulating pressure losses. (Johannes, 2011; Joel et al, 2012). Drilling fluids are also used to avoid formation damage and to limit one of the biggest problems faced in the oil industry "corrosion". (P.F Luckham, 1999). The most commonly used drilling fluids are Water based muds (which can be dispersed and non-dispersed), Oil based muds (non-aqueous muds) and Gaseous drilling fluids (in which wide range of gases are used).

The working of Drilling fluids mainly depends on its properties. The main properties of drilling fluids are: Viscosity, Density, pH of the mud, thermal stability and Gel strength. Oil based and Water based drilling fluids have been found to act diversely in regard to hole cleaning even though their viscosity profiles may have been fairly equivalent. The different behavior is generated by the different ways these drilling fluids are constructed. Oil based drilling fluids are formulated using a continuous oil phase (Martins, 1999). Till now we have discussed about the use of drilling fluids and its advantages in the drilling process, both in offshore and onshore drilling. But, like it's said everything has a negative side, perhaps the biggest problem which must be tackled well otherwise, it may lead into some of the most dangerous situations. In case of drilling mud toxicity is considered as a major issue which must be tackled efficiently otherwise it will lead into many natural disasters. Most of the efficient drilling fluids are of high toxicity and this toxicity is limiting the use of such drilling fluids. In this scenario, the oil industry is in need of something known as eco-friendly drilling fluid, but when we go with that idea of eco-friendly drilling fluid, two things are to be considered: The efficiency of the drilling fluid and the cost of the drilling fluid. Most of the cases we have to compromise either one of these three (eco-friendly, economical, efficiency) or at some cases two of them (H.C.H Darley, 1980). In this paper, an idea has been coined in which all these things are equally balanced. The idea is basically about using two additives with bentonite and make a new drilling fluid which is less toxic and economical. The additives which we use are Glycerol & Psyllium husk. Glycerol is considered as one of the most widely produced waste in chemical industry and which is very less toxic compare to the other drilling fluid additives. Glycerol is a by-product of palm oil biodiesel industry which possess a high potentiality in the application of drilling fluid system. (Kirk & Otmer, 1951). Glycerol is a viscous and polar substance that has been known for its useful properties. (Behr et al, 2008; Guner et al, 2006). Glycerol molecular formula is $C_3H_8O_3$ with molecular weight of 92. It is a chemical compound composed of three hydroxyl group with properties such as high viscosity, odorless, colorless, sweet flavored (0.6 times sucrose), and non-toxic in its original condition. Glycerol has three hydroxyl groups that are responsible for its solubility in water. With its properties such as low price and low toxicity, glycerol applications in drilling fluid is very beneficial comparing to other materials which are broadly used in drilling industries without even considering toxicity and cumulative impact on terrestrial, coastal, and marine habitats. Thus, the development of sustainable material which could produce a highly biodegradable base fluid and can act as an additive for drilling fluid was constructed (V. Mahto, 2004). The main source of availability of glycerol is that it is a waste produced in the biodiesel industry which is eco-friendly in nature. The major applications of glycerol in the Oil drilling sector are: It is capable of stabilizing water sensitive formations, Natural emulsifier of water and is relatively inexpensive, Inhibit hydration on water sensitive clays, Glycerol addition contributes effectiveness in increasing mud lubricity and film strength, Water based mud -glycerol system has good potentiality in handling cutting suspension but it must be accompanied by viscosifier to increase plastic viscosity and yield point, the addition of Glycerol gives a thinner mud cake; thus, glycerol application is very effective in preventing differential sticking problem, Glycerol addition reduce mud filtrate pH, thus glycerol application shall be accompanied with base additive, such as lime or caustic soda. (Marbun, 2013). The second additive which have been used is husk, also known as Psyllium husk which is purely eco-friendly. Psyllium is the seed of plants of the Plantago category and Psyllium Husk is the main product. Psyllium Husk is the separated surface covering of the Psyllium seed. The psyllium seed includes a husk portion that is a cleansed, dried seed coat of the psyllium seed. The husk portion is detached from the seed by winnowing and thrashing. Typically, the husk portion of the psyllium seed is grounded into a husk to make the bulk laxative agent.

Fig 1: Psyllium Husk used for the preparation of drilling fluid

Psyllium seed husk has been used as a fiber supplement and a bulk laxative drug because of its capacity for substantial swelling when ingested. This swelling makes the psyllium husk a useful bulking agent (Guo, Cui et.al. 2009). It is a white to pale brown material with hydrophilic characteristic and is used as a thickener in food industry due to its superior thickening property (Alireza, 2016). Extraordinary gelling property of Psyllium Husk can be used in the oil and gas drilling industry. The water-soluble part of psyllium Husk develops superior rheological characteristics. Hence, Psyllium Husk can be served as a viscosity and filtration agent. The major applications of

Psyllium Husk on Oil drilling sector are: Environment friendly natural polymer, thickening property, Psyllium husk is an exceptional filtration and viscosity agent for water-based drilling mud, it can be used as a clay extender to supplement the viscosity and filtration performance of bentonite mud, Provides additional gelling capacity for the water-based drilling mud. (T. E Gray, 2005). This paper investigates the application of glycerol added psyllium husk in water-based drilling fluids to prepare an eco-friendly drilling mud. Distilled water along with bentonite is added at various concentration to glycerol added psyllium husk in order to examine the rheological characteristics of the mixture. The main objective of this paper is to observe the changes in rheological properties of drilling fluid when these two additives are added. In our future studies we would like to add one more natural additive in form of sugarcane ash which is an eco-friendly waste.

2. MATERIALS USED

For the experiment we have used Psyllium high purity whole husk from Nature Vit, Glycerol (glycerin) from Chemico glass and scientific company, industry grade Bentonite. In order to study the combined effect of psyllium husk and glycerol on the rheological properties of bentonite-based drilling mud, the plastic viscosity, yield point and gel strength were measured for the bentonite-based drilling mud with/without the psyllium husk and/or glycerol. Experiments were performed with fresh water-based drilling mud. We prepared four different types of sets of drilling fluids based on its constituents. For each set of drilling fluids, the composition of its constituents was varied, and its results were recorded.

3. PROCEDURE

Set 1: - This type of fresh water-based drilling mud consists of an adequate amount of water and a certain percentage of Bentonite which is altered to record the changes in its rheological properties such as plastic viscosity, yield point, apparent viscosity and gel strength. The compositions of different designed drilling muds based on the amount of Bentonite are shown in Table 1. A nominal amount of water (based on the equipment feasibility) was taken after measurement by using a measuring cylinder and the requisite amount of bentonite (taken percentage wise) was taken after weighing it on a weigh-scale. The Bentonite and water were taken in the Hamilton Beach mixer (FANN® Instrument Company) for the dispersion of the bentonite clay particles by mechanical shearing provided by the mixer and for the preparation of drilling mud. With each sample of drilling mud prepared, we use FANN® viscometer to record the readings which corresponds to the rheological properties. These readings of $\Theta 300$, $\Theta 600$ and the gel strength (at speed 3) were noted. For a period of 10 minutes we keep the sample undisturbed and the gel strength of the sample is taken again. Note down the readings and register the data on the table. Find out the various rheological properties of the drilling fluid for each sample with the help of equations.

Set 2: - In this set of drilling fluids, to the freshly prepared Bentonite-based drilling mud (consisting of Bentonite and water), we add a certain volumetric percentage of glycerol and test its properties. The various composition of the constituents is given in Table 2. For every sample in this variant of drilling fluid, the amounts of bentonite and glycerol was changed. Glycerol being meticulously measured with the help of a small measuring cylinder, was taken into the mixture of Bentonite and water. This was blended in the Hamilton beach mixture for it to uniformly dissolve in the solution. The prepared solution was transferred to the FANN® viscometer to get the readings of $\Theta 300$, $\Theta 600$ and initial gel strength. The solution was retained in the viscometer for a period of 10 minutes and its final gel strength was noted down. All these readings were registered against the sample mentioned on the table. With the help of the equations mentioned earlier, we find out the PV, YP and AV. The readings of the same would tell us about the properties and is noted down on the table against the sample used.

Set 3: - The third set of drilling fluids consists of a mixture of water, Bentonite and Psyllium husk. High purity psyllium whole husk is taken by weight percentages and is agitated in the Hamilton beach mixture with the solution of water and bentonite. (The compositions of different designed drilling muds are shown in Table 3). This sample is taken in the FANN® viscometer to find out the readings which would help us find the rheological properties. The equations would help us find the other properties. The readings and the values are recorded and registered on the table.

Set 4: - Our final set of drilling fluids which is our objective drilling mud of interest, is a blend of water, Bentonite, glycerol and Psyllium husk. For the combined effect of psyllium husk and glycerol, we measure them and mix it with the bentonite-water based drilling fluid. Drilling muds are prepared with different amounts of bentonite, glycerol and psyllium husk. The compositions of different designed drilling muds are shown in 4 different tables. All the constituents are taken and blended in the Hamilton beach mixer. This sample is transferred to the FANN® viscometer with which we down the readings of ϴ300, ϴ600 and initial gel strength. The sample is kept idle and undisturbed for 10mins and the final gel strength is noted. The date is tabulated. Refined analysis and presentation of data on a table is done. With the help of the data for all four sets of drilling fluids, graphs are plotted for comparison and analysis.

EQUATIONS

P. V= ϴ600 - ϴ300 cP; Y. P= ϴ300 - P.V lb./100 sq. ft.; A. V= ϴ600/2 cP
Where, P.V- Plastic Viscosity, Y.P- Yield Point, A.V- Apparent Viscosity.

3.1 SAMPLE COMPOSITION AND RESULTS OBTAIN

Table 1: Samples with Bentonite + Water

SAMPLE 1										
Sample No	Water (mL)	Bentonite		Θ_{600}	Θ_{300}	Gel Strength (lb/100sq ft)		PV (cP)	YP (lb/100sq.ft)	AV (cP)
		(%)	Gram(gm)			Initial	Final			
Sample 1	400	2	8	2.2	2	0.1	0.1	0.2	1.8	1.1
Sample 2	400	3	12	3	2	0.1	0.1	1	1	1.5
Sample 3	400	4	16	5	3	0.5	0.4	2	1	2.5
Sample 4	400	5	20	7.5	5	2.3	2.3	2.5	2.5	3.75

Table 2: Samples with Bentonite + Water + Glycerol

SAMPLE 2												
Sample No	Water(mL)	Bentonite		Glycerol		Θ_{600}	Θ_{300}	Gel Strength (lb/100sq ft)		PV (cP)	YP b/100sq.ft	AV (cP)
		%	gm	%	ml			Initial	Final			
Sample 5	400	2	8	0.5	2	4	3	5	4	1	2	2
Sample 6	400	3	12	1	4	6	4	3	3	2	2	3
Sample 7	400	4	16	1.5	6	6	4	4	3	2	2	3
Sample 8	400	5	20	2	8	7.5	5.5	3	3	2	3.5	3.75

Table 3: Samples with Bentonite + Water + Glycerol + Psyllium Husk

SAMPLE 3												
Sample No	Water(mL)	Bentonite		Husk		Θ_{600}	Θ_{300}	Gel Strength (lb/100sq ft)		PV (cP)	YP b/100sq.ft	AV (cP)
		%	gm	%	gm			Initial	Final			
Sample 9	400	2	8	0.5	2	11	6	12	9	5	1	5.5
Sample 10	400	3	12	1	4	25	18	26	40	7	11	13
Sample 11	400	4	16	1.5	6	90	70	37	30	20	50	45
Sample 12	400	5	20	2	8	90	73	140	150	17	56	45

Table 4: Samples with Bentonite + Water + Glycerol + Psyllium Husk + Glycerol

SAMPLE 4														
Sample No	Water(mL)	Bentonite		Glycerol		Husk		Θ_{600}	Θ_{300}	Gel Strength (lb/100sq ft)		PV (cP)	YP (lb/100sq.ft)	AV (cP)
		%	gm	%	ml	%	gm			Initial	Final			
Sample 13	400	2	8	0.5	2	0.5	2	15	9	20	18	6	3	7.5
Sample 14	400	3	12	1	4	1	4	40	34	35	33	6	28	20
Sample 15	400	4	16	1.5	6	1.5	6	65	47	67	55	18	29	33
Sample 16	400	5	20	2	8	2	8	94	70	130	120	24	46	47

4. RESULTS AND DISCUSSIONS

Rheological properties of drilling mud after adding the mixture of glycerol added psyllium husk has been tested for various concentrations. PV, AV, YP and Gel strength has shown standard variation with respect to conventional drilling mud.

The first comparison was based on the variation of the apparent viscosity in terms of solid loading (Percentage composition of bentonite). It is clearly shown in the graph (Chart 1) how the plastic viscosity has been increasing for sample (13-16) comparing to others. Taking into account for Sample (1-4), it shows the maximum value of 2.5cp which shows less effectivity when compared to the sample (13-16) which is having a viscosity of 24cp (Chart 1). The more the PV the more will be the ability of the fluid to remove cuttings from the well bore. The experiment shows that, for a solid loading the mixture of psyllium added drilling fluid is offering the maximum viscosity. The PV will not only help in effective removal of cuttings but also increase the ROP due to decrease in the differential pressure across the formation. Though many of the additives used are delivering good effects in the field it is also creating problems to the environment. In this case the mud prepared is showing greater efficiency in the field as well as creating a positive impact to the environment without the emission of any toxic gases.

The graph (Chart 2) clearly shows that the sample containing Water + Bentonite + Husk + Glycerol is having the highest apparent viscosity of 47cp comparing to the nominal sample used as drilling mud. For a solid loading of 8% the AV offered by the conventional drilling fluid is 3.75cp whereas the glycerol added psyllium husk WBM is giving an AV of 47cp. The mixture of Husk + Bentonite + water is also showing a descent viscosity of 45% but the reason for neglecting is due to the poor wettability and dispersibility offered by psyllium husk which in term fails to satisfy many unexpected scenarios in the oil field. Both Apparent and Plastic Viscosity has been improved by the addition of Husk and Glycerol on to Bentonite based drilling fluid.

The Yield point is slightly a bit higher for the Recipe 3 than Recipe 4. Though the value is less for this small-scale experiment it will enhance the drilling fluid properties in a larger manner. For the maximum solid loading of 8% the conventional drilling fluid is offering YP of 2.5 lb./100 sq. ft. whereas the glycerol added Psyllium husk WBM gives YP of 46 lb./100 sq. ft. (Chart 3). For the same concentration of 8% Psyllium hush mixed drilling fluid shows the maximum of 56 lb./100 sq. ft. which is highest among all the recipes prepared. The recipe 4 will show a greater attractive force among the colloidal particles in the drilling fluid which causes the force required to carry the cuttings. The YP is larger for recipe 4 comparing to 1 pointing out the efficiency in the task of removing the drill cuttings. The proposed mixture of glycerol added Psyllium husk will offer higher Equivalent Circulating Density (ECD) comparing to recipe 1 and also indicates higher bore hole cleaning which will reduce the chances of contamination of the well. It may be mentioned that higher is the YP of the drilling mud in the optimum, better will be ability of the mud system to keep the cuttings in the dynamic suspension while drilling.

The initial and final Gel Strength was found to be more for the Recipe 3 comparing to all the others. Hence it reduces the probability of building up of cutting beds within the formation thereby reduces the chance of differential sticking and also offers negligible structural damage. Recipe 4 was found to offer more gel strength comparing to the normal bentonite-based drilling mud. For the bentonite concentration of 8 % Recipe 1 is showing an initial and final gel strength of 2.3 and 2.3lb/100 sq.ft (Chart 4, Chart 5) whereas the glycerol added Psyllium husk is showing 120 and 130lb/100 sq. ft.

This shows as the wettability and dispersibility of the husk has a major hand in the alteration of rheological properties of the drilling mud. Varying with the addition of glycerol to the Psyllium husk, the properties are showing a great response. By attaining a higher gel strength, the drilling mud possess the ability to keep the cuttings in the suspended conditions to fulfil the functional task of the mud during the period of non-circulation. Following table shows the difference in the magnitude of rheological properties shown by the conventional drilling fluid and the glycerol added Psyllium husk mixture on drilling mud for the maximum solid loading of 8%.

Table 5: Results obtained on rheological properties using conventional drilling fluid and the glycerol added Psyllium husk mixture on WBM.

Rheological Properties	Bentonite + Water	Bentonite +Water + Psyllium husk + Glycerol
AV (cp)	2.5	24
PV (cp)	3.75	47
Yield point (lb/100 sq.ft)	2.5	46
Initial Gel Strength (lb/100 sq.ft)	2.3	130
Final Gel Strength (lb/100 sq.ft)	2.3	120

5. CONCLUSION

In this study, four samples had been prepared and rheological properties such as apparent viscosity, plastic viscosity, yield strength and gel strength had been studied and verified. It was found out experimentally that the mixture containing Glycerol added psyllium husk on Bentonite based drilling mud was having more efficiency and all the properties were exceptionally high for this mixture and will prove to be an effective drilling mud in the industry. The main concept of availability and environmental friendly are the standout qualities for this drilling mud. Result of this study suggests that Psyllium husk and Glycerol on bentonite-based drilling mud can be used as a natural additive to develop viscosity and other rheological properties. The eco-friendly additives used to generate the psyllium husk added drilling mud will eliminate any environmental impact to the surrounding environment, habitats, ecosystem and thus expected to play a vital role in protecting the global environment. The avenues that can help reduce drilling coast and time are increased rate of penetration (ROP), reduction in drilling problems, improvement of hole cleaning efficiency, reduction of mud management cost and elimination of non-productive drilling time. The newly generated drilling mud used in this experiment will have a major role in the reduction of current and future drilling cost. Glycerol added psyllium husk on drilling fluid is not only a contaminant tolerant but also an eco-friendly drilling mud. Thus, it has no detrimental effect to onshore and offshore environment if the mud is used in these conditions. Glycerol added psyllium husk on drilling mud has great ability in taking care of cutting suspension and it gives a slender mud cake, hence the application is exceptionally successful to keep any differential sticking issues. The proportionality delivered by glycerol and psyllium husk gives an option to the mud engineer to manipulate the rheological parameters required for the well in different conditions.

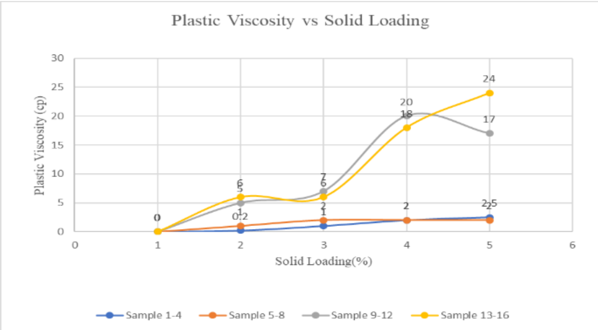

Chart 1: Comparison of Plastic Viscosity for various samples

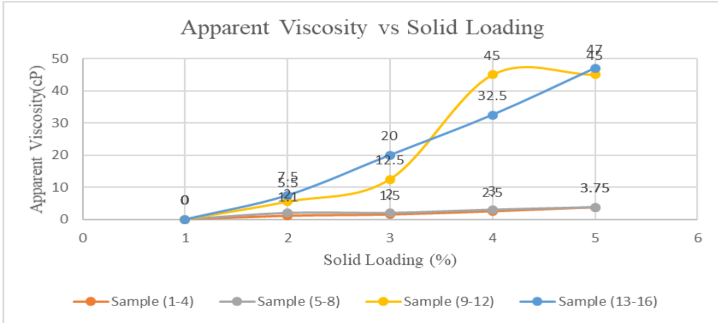

Chart 2: Comparison of Apparent Viscosity for various samples

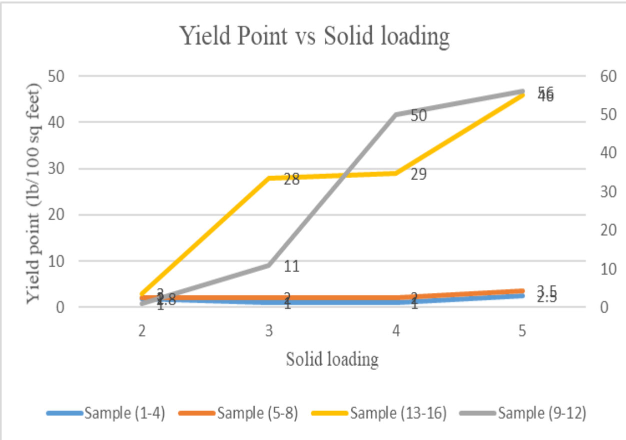

Chart 3: Comparison of Yield Point for various samples.

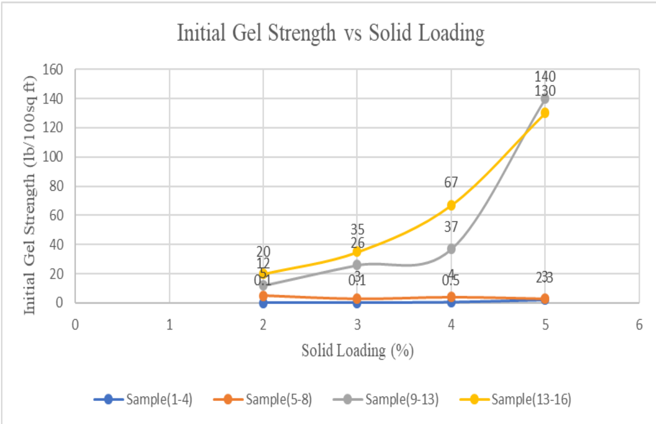

Chart 4: Comparison of Solid Loading with Initial Gel Strength

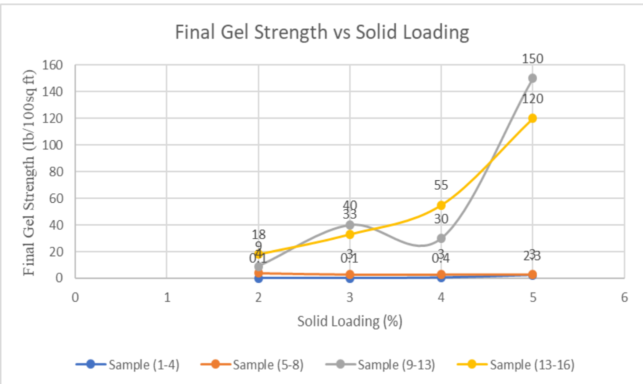

Chart 5: Comparison of Solid Loading with Final Gel Strength

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