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ANALYTICAL STUDY OF NOVEL STARCH POLYMER BLEND FOR WATER-BASED DRILLING MUD APPLICATION

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Abstract: Major problems have been encountered during drilling operation, most of which are; fluid loss, wellbore strengthening, well control, carrying capacity, torque and drag, stuck pipe, and others, which can result from the improper matching of drilling fluid properties. These problems occur due to dissimilarity in pressure, and temperature whose effect is mostly observed on the rheological properties. Drilling mud has proven to be modified over the years with researchers continuously working earnestly to produce a drilling mud of good drilling properties, environmental friendliness and less expensiveness. The main goal of this study is to develop a water-based drilling mud containing biodegradable polymer blend produced by Extrusion technique, with good temperature and pressure properties capable of surviving deep well temperature drilling. The experiment involved the formulation of new polymer mud from blend of guinea corn and popcorn starches tagged as **G:P-Mud**, where its values obtained from the experiment was compared to an already existing polymer mud tagged as **CMS:HPS-Mud**. At different temperature range (25°C, 180°C, 240°C, 300°C) and concentration of 0.03g/ml, the highest Sorptivity value was obtained to be 31.62 at 300°C for new starch polymer drilling mud (**G:P-Mud**) while that of chemically modified starch (**CMS:HPS-Mud**) was found to be 17.93. Fluid loss value for new polymer mud (**G:P-Mud**) at 300°C was obtained to be 266.00 while that of **CMS:HPS-Mud** was obtained as 736.00. It was deduced therefore that the new polymer drilling mud had a better filter cake property, filtration control behavior, thermal stability, good carrying capacity and lower fluid loss value than the chemically modified drilling mud. The experiment followed API standardized testing procedures for drilling equipment, drilling fluids and API recommended practices.

Index Terms- Corn, Drilling mud, Extrusion, Fluid loss, Polymer blend, Starch.

1. INTRODUCTION

Drilling mud, which is also known as drilling fluid in petroleum drilling is a heavy and viscous fluid mostly used in a drilling operation to move rock cuttings to the surface of the earth, and to cool drill bit (Chike et al., 2020; Britannica, 2017). Drilling mud prevent the collapse of unstable rock strata into the drilling wellbore and intrusion of water flow that may be encountered during drilling (Anderson, 2017). Most of the common problems encountered are poor fluid loss control, poor carrying capacity of mud, low viscosity, poor rate of filtration, low pressure performance, poor torque performance of drill bit and wellbore instability (Albert and Mandy, 2015; Ghazi et al., 2008). This problem results from poorly produced drilling mud. It is said that about one fifth of the problems of drilling operation is attached to inadequacy of drilling mud (Khodja et al., 2010). There are several requirements of a drilling fluid to perform effectively which are; good fluid rheology characteristics, low cost, environmentally friendliness, capacity to reduce drilling cost and time, and lastly, must minimize recycling to reduce environmental foot print. It is also noted strongly that the successful completion of a drilling operation depends on the properties of the fluid hence the need for a well-designed fluid with improved drilling efficiency (Kazi et al., 2018).

There are various types of drilling mud used in drilling, which are; Water-based drilling mud: these are the most widely used type of fluids and they are considered less expensive than all other type of fluid. Up to about 80% of drilling operation are carried out using water-based fluid (Hardy et al., 2015; Vander-Zwaag, 2006) The base or starting fluid of W-B fluid is usually, fresh water, sea water, brine solution etc. further substances added are clay (bentonite clay) and other chemicals, for example; potassium phosphate, to create a homogenous blend (Robert, 2017). We, also, have Oil-based drilling fluid, which was the earliest form of fluid produced to solve issues like; clay formation that causes swelling, high temperature at the bottom, contamination, stuck pipe, torque and drags. These fluid have their base substance as diesel, mineral oil, low toxicity linear olefins and paraffin (Chike et al., 2020). Oil based muds are mostly used for many reason such as; increased lubricity, greater cleaning abilities with less viscosity, temperature control, shale inhibition (Mason and Gleason, 2013). On the other hand, oil-based fluids have some limitations to an extent, as well as synthetic-based fluid (Chike and Okezie, 2021). Synthetic-based fluids were developed as a result of the desire to reduce environmental impact of oil-based fluid, but has been costly to prepare for use (Kenz, 2014; Lyons et al., 2011). The intention for production include among others, high control of flow rate, and increase in gel yielding.

Meanwhile, water-based drilling mud as produced in this work is non-toxic. The water-based drilling fluid has, for long, been formulated with polymer based-additives, which could be non-degradable and toxic. This present research contains the water-based drilling mud produced with biodegradable polymers, blend of starches of varying origins, which aid to solve most of the problems pertaining to some drilling mud. The polymer based mud is cheap because its source can be obtained from local market or farm. It is environmentally friendly, due to its ability to decompose quickly after use. It has good technical performance, in that, it can still function effectively at high temperatures. There have been great needs to provide high performance drilling fluids for operations at temperatures of over 200°C (Robert, 2017; Bhattacharya et al., 2002). Some experiments had proved detailed steps taken to produce water-based polymer drilling mud from starch of varying sources (Scott et al., 2013; James, 2012; Jax, 2010).

2. MATERIALS

Materials used for extraction of the starch and preparation of the mud were; Popcorn (zea mays everta), Guinea corn (sorghum vulgare), Sodium Hydroxide (NaOH), Carboxymethyl and Hydroxypropyl starch blend (Standard and already existing), Bentonite clay, double distilled water.

3. METHODOLOGY

3.1. Preparation of Samples

Preparation of the mud occurred in three different steps, which are; Extraction of starch, Extrusion/blending of starches, and mud preparation**.**

3.1.1. Extraction of Starches

The extraction was done by hand picking the corn grains, which later, was kept in water to soften for 12hrs. It was then removed from water and pulverized to obtain a thick-muddy fluid. The thick fluid was pressed through a cloth into distilled water. The extract was kept for an hour to form, after which the water is filtered out and the remaining mixture was left for a day under open air to dry.

3.1.2. Extrusion/Blending of Starches

The starches obtained from the above step were used to produce a blend of Guinea corn and Pop corn starch extract used in this work as **G:P**. These starches were pre-gelatinized, mixed and blended using extrusion technique without any solvent or chemical. The blending of both starches was done by mixing the starches with water in a ratio of 85:85:45. The, the blending was carried out with an extruder. The extruded starch was then chopped in into small sizes of 2-3mm. The chopped samples were dried at a temperature of 105°C, and ground to obtain powdered sample of much less fraction particle’s size.

3.1.3. Preparation of Muds

During preparation, bentonite clay, one of the components for drilling mud, was mixed with distilled water for 30min with the use of a mixer. After mixing the grounded starch blend (millet and pop corn starch) was gradually put in the bentonite with continous stirring to prevent cake development in the system. Thereafter, 25ml of sodium hydroxide (NaOH) was introduced to alter the pH solution of the system and to prevent corrosion of drill bit. The final process yielded a new polymer drilling mud having 0.03g/ml concentration of starch and 6% bentonite clay with good thickness was obtained as (**G:P-Mud**). Another standard drilling mud used for comparison having similar starch concentration of 0.03g/ml in distilled water is tagged as (**CMS:HPS-Mud**).

3.2. EXPERIMENTAL METHOD

3.2.1. Filter Loss Method

Fluid loss refers to the volume of filtrate lost to the permeable material due to the process of filtration. This is a standard method by which the filtration properties of drilling mud is determined. In this process, the component slurry was separated by leaving the suspended solids as filter cake on a filter medium while the main fluid was alllowed to pass through. This test was conducted using a static filter press device. The test was conducted at different temperature of 25°C, 180°C, 240°C and 300°C. The average of the test was taken. The results obtained were recorded.

3.2.2. Sorptivity (S) of the Mud.

Philip John R. in 1957, carried out studies on "The theory of filtration: Sorptivity and algebraic filtration equations" (Mason and Gleason, 2013; Lyons et al., 2011). The term sorptivity is defined as a measure of the capacity of the medium to absorb or desorb liquid by capillarity (Jax, 2010). Recently, Sorptivity has, also, been defined as the ability of a material to absorb and transmit fluids like water or other liquids (Robert, 2017). The Sorptivity (S) was computed using eqn. 1, according to American Petroleum Institute, API, (Robert, 2017; Jax, 2010; Jann et al., 2007).

$$V=St^{½} \quad \text{---} \quad (1)$$

Where V is the filtrate volume or fluid loss or filter loss, S is the sorptivity of fluid, and was obtained as the slope of the plot, t is the filtration time in minutes. Its unit is given as $m.s^{-1}$.

3.2.3. Diffusivity (D) of the Mud.

The Diffusivity (D) is the mesasure of the rate at which particles of the mud can spread through the drill bit during drilling operation (Robert, 2017; Jax, 2010; Jann et al., 2007).
It was computed using eqn. 2.

$$\Phi(R) = \Phi_o \exp^{-Dt} \quad \text{--} \quad (2)$$

Where Φ_o and Φ are initial and final filtration rates respectively,
D is the diffusivity of fluid, and was obtained as the slope of the plot, t is time in minutes.

Table 1: Experimental Data and Results for the Filtration Properties of the Muds (G:P–Mud and CMS:HPS-Mud) with 0.03g/ml Starch concentration at 25ºC, 180ºC, 240ºC, 300ºC Temperatures.

				G:P–Mud		CMS:HPS-Mud	
Temp ºC	Time t (mins)	Conc (g/ml)	Square Root of Time, $t^{1/2}$ (mins)	Fluid loss, filtrate volume, V (ml)	Rate of filtration, (ml/min)	Fluid loss, filtrate volume, V (ml)	Rate of filtration, (ml/min)
25ºC	50	0.03	7.07	75.00	1.50	140.00	2.80
	100	0.03	10.00	92.00	0.92	171.00	1.71
	150	0.03	12.25	104.00	0.69	191.00	1.27
	200	0.03	14.14	112.00	0.56	210.00	1.05
	250	0.03	15.81	119.00	0.48	223.00	0.89
	300	0.03	17.32	125.00	0.42	234.00	0.78
180ºC	50	0.03	7.07	145.00	2.90	215.00	4.30
	100	0.03	10.00	158.00	1.59	232.00	2.32
	150	0.03	12.25	170.00	1.13	247.00	1.65
	200	0.03	14.14	181.00	0.91	260.00	1.30
	250	0.03	15.81	190.00	0.76	272.00	1.09
	300	0.03	17.32	194.00	0.65	280.00	0.93
240ºC	50	0.03	7.07	162.00	3.24	240.00	4.80
	100	0.03	10.00	176.00	1.76	267.00	2.67
	150	0.03	12.25	189.00	1.26	298.00	1.99
	200	0.03	14.14	201.00	1.01	318.00	1.59
	250	0.03	15.81	211.00	0.84	336.00	1.34
	300	0.03	17.32	220.00	0.73	348.00	1.16
300ºC	50	0.03	7.07	195.00	3.90	397.00	7.94
	100	0.03	10.00	215.00	2.15	475.00	4.75
	150	0.03	12.25	232.00	1.55	550.00	3.67
	200	0.03	14.14	248.00	1.24	618.00	3.09
	250	0.03	15.81	261.00	1.04	677.00	2.71
	300	0.03	17.32	271.00	0.90	738.00	2.46

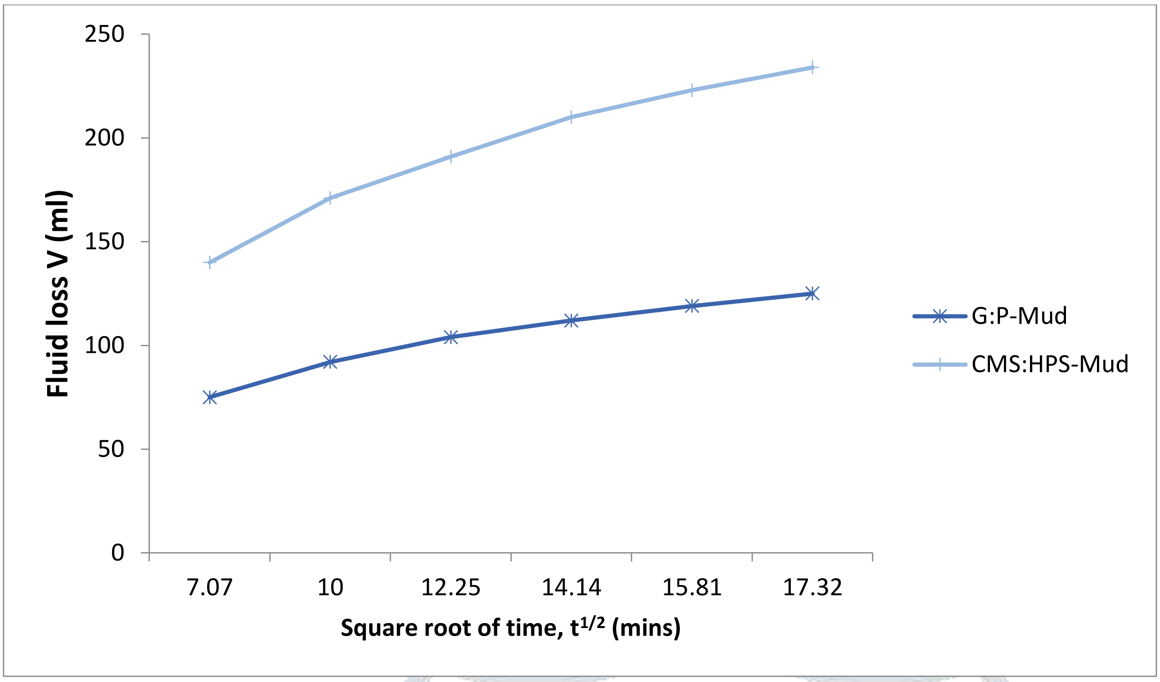

Figure 1: Plot of Fluid Loss versus Square Root of Time for the Muds (G:P-Mud and CMS:HPS-Mud) with 0.03g/ml Starch Concentration at Room Temperature, 25°C.

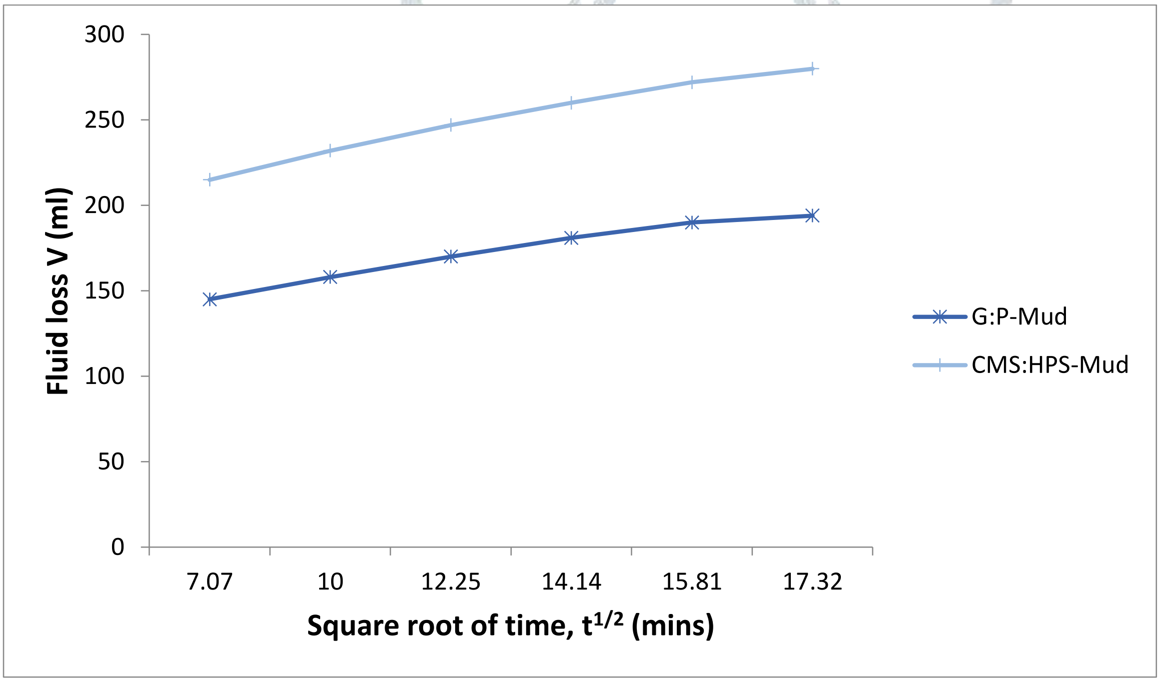

Figure 2: Plot of Fluid Loss versus Square Root of Time for the Muds (G:P-Mud and CMS:HPS-Mud) with 0.03g/ml Starch Concentration at increased Temperature of 180°C.

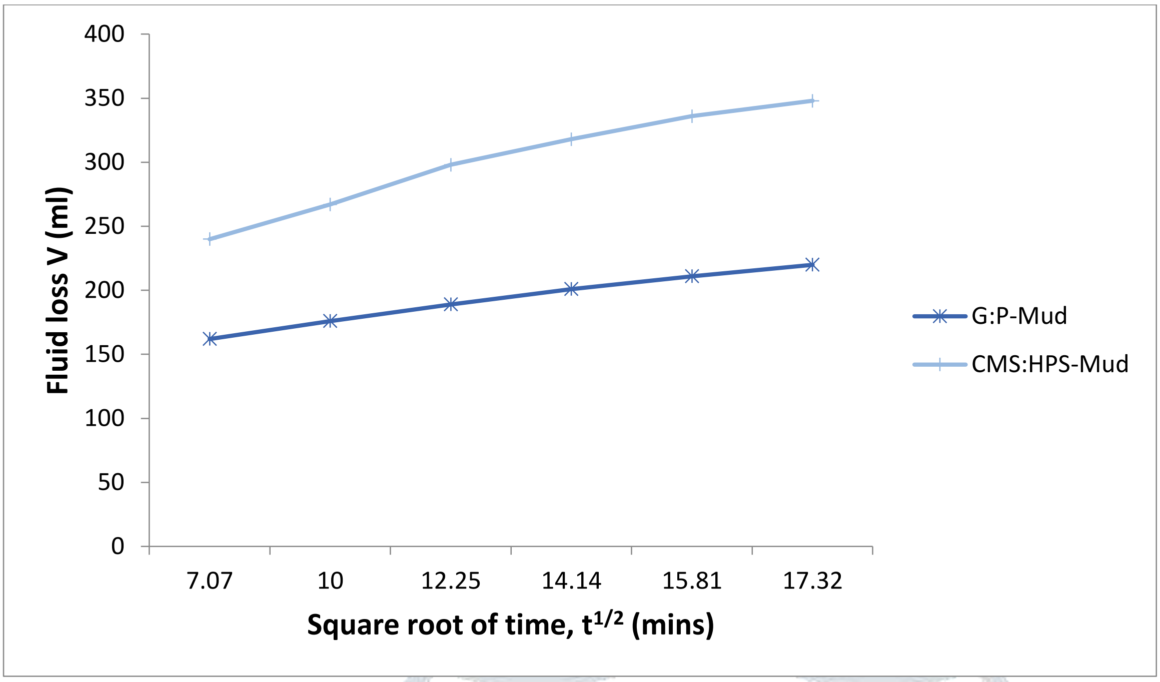

Figure 3: Plot of Fluid Loss versus Square Root of Time for the Muds (G:P-Mud and CMS:HPS-Mud) with 0.03g/ml Starch Concentration at Temperature of 240°C.

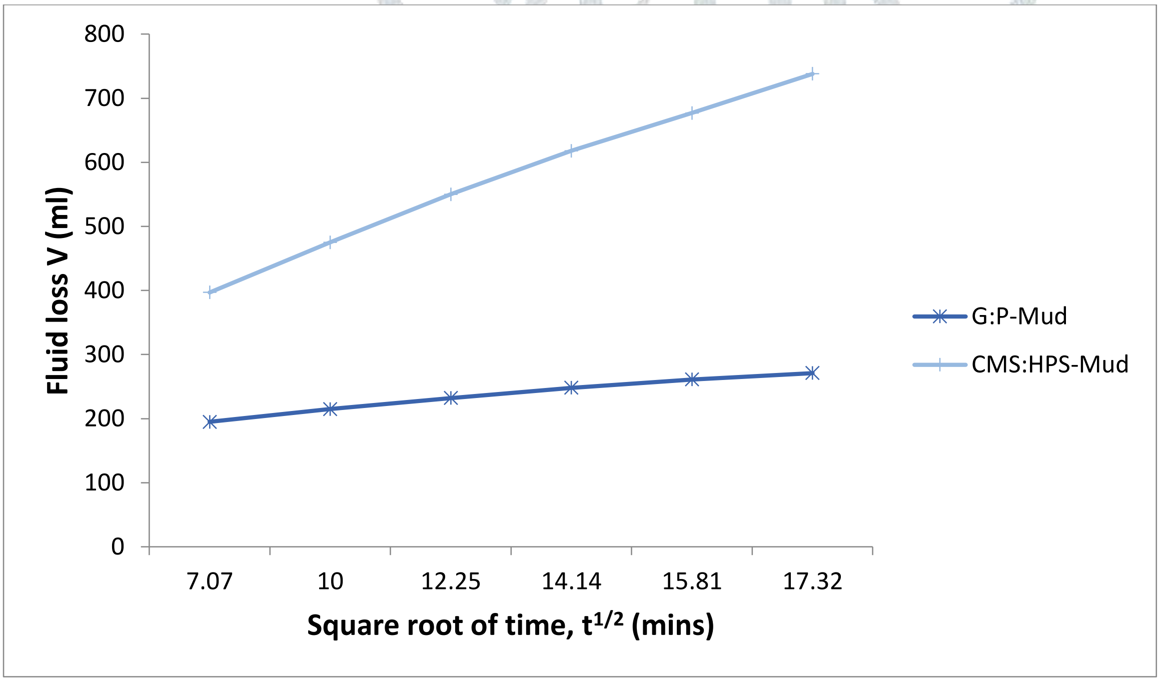

Figure 4: Plot of Fluid Loss versus Square Root of Time for the Muds (G:P-Mud and CMS:HPS-Mud) with 0.03g/ml Starch Concentration at Temperature of 300°C.

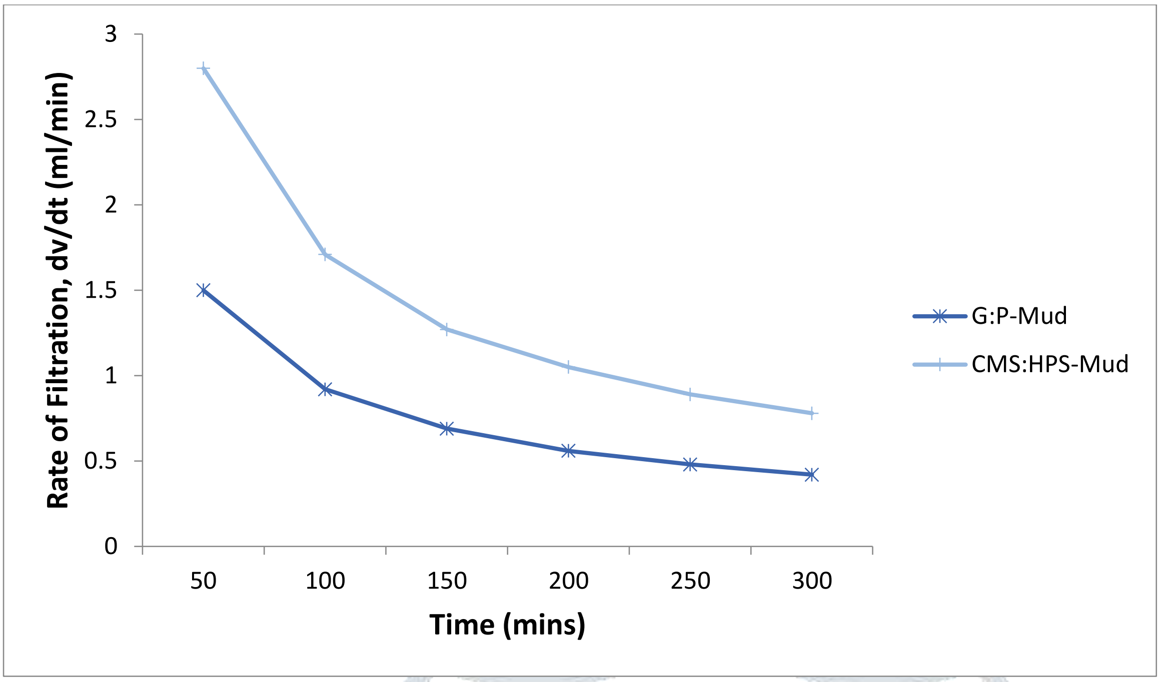

Figure 5: Plot of Rate of Filtration versus Time for the Muds (G:P-Mud and CMS:HPS-Mud) with 0.03g/ml Starch Concentration at Room Temperature, 25^oC.

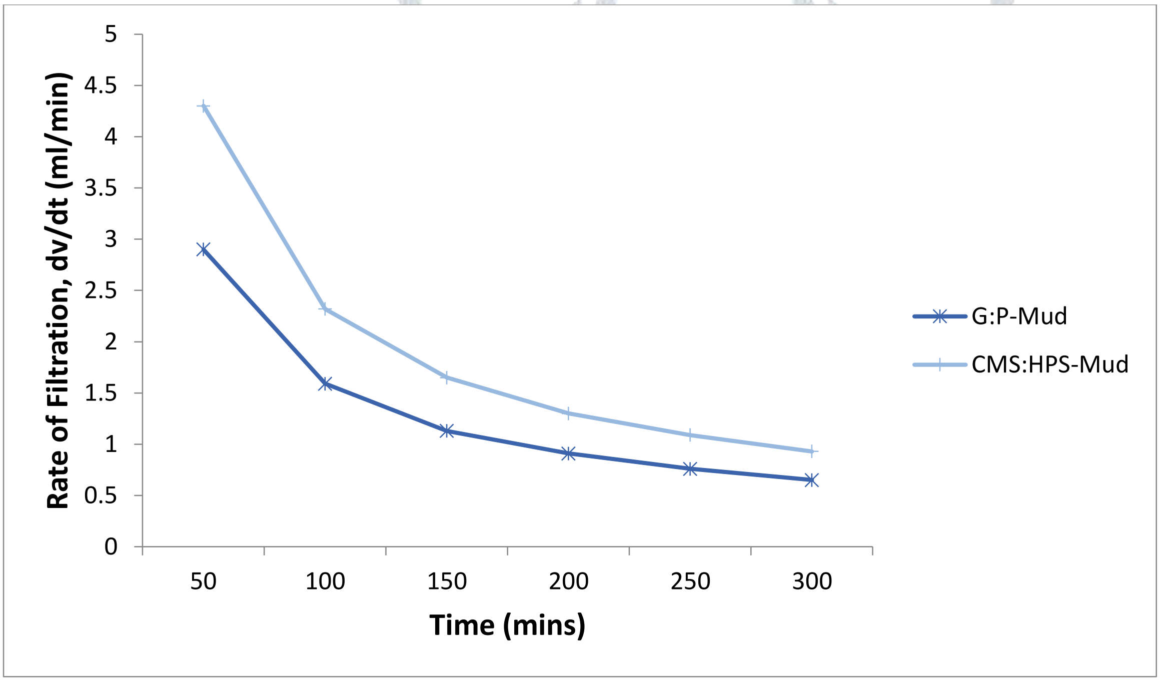

Figure 6: Plot of Rate of Filtration versus Time for the Muds (G:P-Mud and CMS:HPS-Mud) with 0.03g/ml Starch Concentration at increased Temperature of 180^oC.

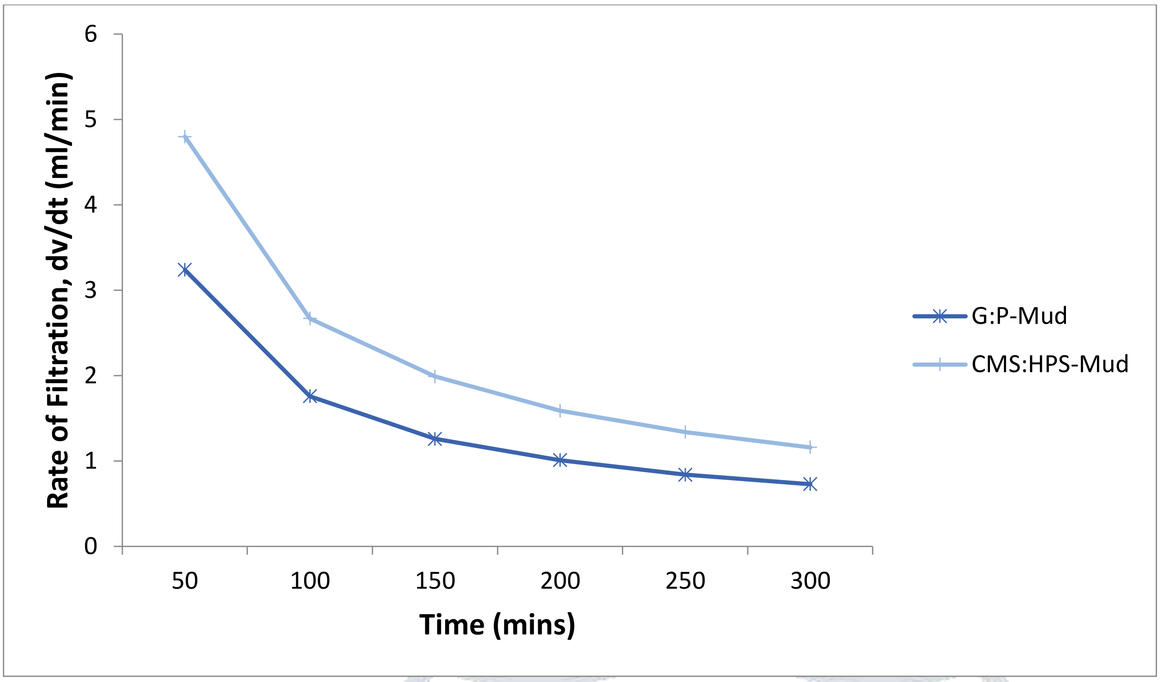

Figure 7: Plot of Rate of Filtration versus Time for the Muds (G:P-Mud and CMS:HPS-Mud) with 0.03g/ml Starch Concentration at increased Temperature of 240ºC.

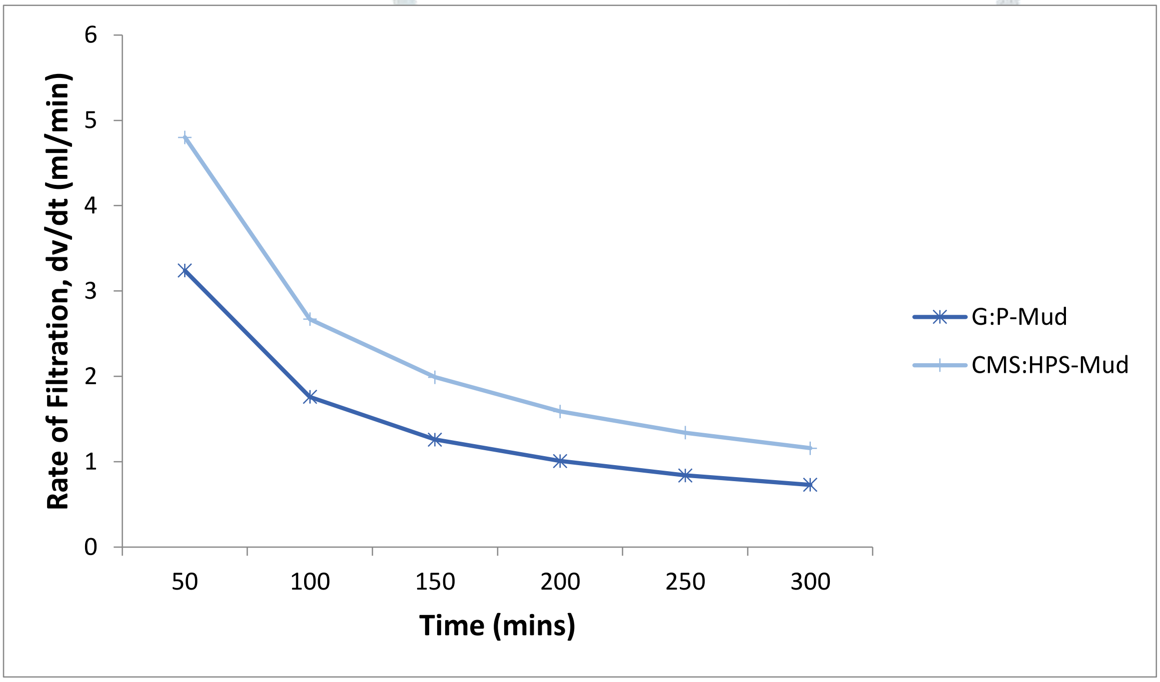

Figure 8: Plot of Rate of Filtration versus Time for the Muds (G:P-Mud and CMS:HPS-Mud) with 0.03g/ml Starch Concentration at increased Temperature of 300ºC.

4. RESULT AND DISCUSSION

The above graphical representation of fig.1-4 depicts the experiment in concordance to API law of filtration which states that, an increase in fluid loss is directly proportional to square root of time. The highest values obtained for fluid loss of both samples are 271.00ml and 738.00ml for **G:P-Mud** and CMS:HPS-Mud respectively. These values were obtained at the highest testing temperature given to be 300ºC. Firstly, it shows that the fluid flow increases as temperature increases. Therefore, it indicated that as there was increase in temperature, the more fluid molecules were expanded for free movement. In the actual drilling, the expansion of the molecules causes them to be more excited to move freely and easily through chambers of the drill bit (Kazi, 2018).

Moreover, such controlled flow makes the starch molecules to perform effectively. Also, it indicated that an increase in temperature caused an increase in fluid volume, resulting in less molecular friction, leading to an increased flow of fluid effectively (Chike et al., 2020). Again, the increased temperature at 300ºC led to a decrease in cake formation due to the weakness of the starch, which was caused by the high temperature. Fig. 5-8 show that the rate of filtration for all the muds decreases with time, which implies exponential decay of filtration behaviors of both muds with time (Robert, 2017).

Table 2: Values of Sorptivity, S of the Muds at all the Temperatures under study.

Temperature	G:P-Mud	CMS:HPS-Mud
25ºC	47.95	35.01
180ºC	43.24	28.35
240ºC	36.76	24.24
300ºC	32.57	17.52

As initially explained, Sorptivity is the measure of the capacity of a drilling medium to absorb or desorb liquid by capillarity (Robert, 2017; Mason and Gleason, 2013; Jax, 2010). The values of fluid sorptivity for the muds at the different temperatures were obtained as the slope of the curves of each plot of fluid loss versus square root of time (Robert, 2017; Jax, 2010; Amani, 2010). The formulated new polymer mud produced higher sorptivity values, and yielded much more favorable results than the series of values obtained from the already existing mud at all temperatures. The procedure for designing a fluid that have a great ability to absorb and retain parts of the flowing fluid, thereby, reduce fluid loss more than the already existing muds at the different temperatures was achieved.

Table 3: Values of Fluid Diffusivity, D of the Muds at all the Temperatures under study.

Temperature	G:P-Mud	CMS:HPS-Mud
25ºC	0.06	0.10
180ºC	0.095	0.17
240ºC	0.15	0.33
300ºC	0.33	0.70

The above Table 3 shows the values of diffusivity of fluid, D. The diffusivity values from the above table 3 showed that the already existing mud had higher diffusivity than the new mud, showing that the former is not suitable for drilling operation, as it will increase cost and poor drilling. All the values of the mud's fluid Sorptivity and Diffusivity obtained at all the temperatures are in much agreement with the American Petroleum Institute, API, model (Robert, 2017; Jax, 2010).

5. CONCLUSION

The results of the Sorptivity S at 25ºC, 180ºC, 240ºC and 300ºC, showed that as temperature increases, Sorptivity (which is slope of the plot) decreased. The fluid sorptivity values of the new mud (**G:P-Mud**) were higher than those of already existing mud (**CMS:HPS-Mud**) at all the temperatures under study. It was, therefore, deduced that a simple and direct approach has been presented for selecting the better drilling fluid with better flow features, better filtration or fluid loss control ability, and suitable for any drilling operation. Additionally, the American Petroleum Institute, API, model can be applied with high confidence to predict the fluid loss and filtration properties of the polymer drilling mud. Lastly, from the study, the new polymer mud has better rate of filtration and fluid loss property than the already existing chemically modified mud. This work, therefore, states that it is advisable for drilling industries to consider the new starch polymer blend in drilling operation.

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