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EXPERIMENTAL EVALUATION OF LOCAL CASSAVA STARCH AS A VISCOSIFIER IN WATER-BASED MUDS

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ABSTRACT: *Water-based drilling muds were designed with imported hydroxyethylcellulose, local bentonite, and cassava starch respectively and rheological properties under reservoir conditions were determined. Upon the concentrations of 0.5 %, 1.0 %, 1.5 %, and 2.0 % of each of viscosifiers, a linear relationship between shear stress and the shear rate at temperatures ranges of 80^oF to 190^oF were established. Although, upon 2.0 % concentration hydroxyethyl cellulose-based drilling fluid lost its fluidity. However, the rheological properties performance of bentonite and cassava starch-based drilling muds were considerably lower and it could be associated with the cassava starch cultivar and bentonite species used. Furthermore, this experimental study reveals the effect of temperature on imported hydroxyethylcellulose, local bentonite, and cassava starch water-based drilling muds and it was observed that as the temperature increased from 80 ^oF to 190 ^oF, the drilling muds experienced shear-thinning tendency. No doubt, the experimental study has revealed that imported hydroxyethylcellulose, local bentonite, and cassava starch are rheological enhancers in water-based drilling mud therefore could be recommended for drilling operations although will have little modification and beneficiation of local cassava starch and bentonite.*

KEYWORDS: *Shear stress, Shear strain, shear-thinning, Slurry weight, Rheological behavior*

INTRODUCTION

The successful completion of an oil and gas well and production of hydrocarbons from the oil and gas reservoir depends to a considerable extent on the properties of drilling fluids selected during drilling operations. The selection of the right fluid and the maintenance of the properties primarily influence the production rate while drilling Caenn et al (2011). The authors stated that drilling fluids are classified into three categories according to their continuous phases such as water-based fluid, oil-based fluid, and gas-based fluid. A typical water-based mud usually consists of a suspension of clay particles in water. The optimization of a formulation of a drilling mud can be reduced significantly the overall cost of drilling a well (API, 1968; Garcia and Parigo, 1968). For this purpose, the drilling mud is chosen according to the formation lithology, temperature, and pressure, cost and logistics, environmental and health considerations. The complex fluids play several functions simultaneously. They are supposed to clean the well, hold the cuttings in suspension, reduce friction between the drill string and sides of the well, maintain the stability of the wellbore, prevent the fluid loss to the formation to avoid formation damage and differential pipe sticking by making thin impermeable filter cakes, cool and lubricate the drilling tools and most importantly helps in the evaluation of formation by raising the cuttings from the wellbore bottom to the surface, Lummus and Azar

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(1986) Mahto, 2013). The important rheological characteristics required of drilling fluid for good operational performance are that it should be capable of sustaining sufficiently large stress to maintain cuttings in suspension, particularly when fluid circulation is stopped, whilst having a low enough viscosity for efficient pumping. In steady shear flow, the first characteristic has traditionally implied high yield stress (ie finite stress which must be exceeded before the fluid will flow), and the second, shear-thinning (ie a rapidly decreasing effective viscosity as shear rate, is increased). According to Neil and Geoffrey (1989), in water-based drilling fluids, these characteristics are most commonly achieved using a suspension of bentonite. Apart from suspension bentonite other viscosifiers are added to enhance and improve the rheological properties of drilling fluids such as 1. Attapulgite; is used to provide viscosity in saltwater muds; 3. Guar gum: it provides viscosity and fluid loss control in low solids muds; 4. Hydroxyethyl cellulose: it provides viscosity in brine workover/completion fluid and water based muds; 5. Sodium Carboxy Methyl Cellulose (CMC): it is fluid loss control and viscosifier; 6. Derived Starch: it is fluid loss control and viscosifier; 7. Polyanionic cellulose (PAC) premium grade: it is used as fluid-loss control and viscosifier and 8. Preserved Polysaccharide: non-fermenting starch: it is used for fluid loss control, viscosity, and shale stabilization in salt water and fresh water muds. However, there are various studies in the literature regarding the change in rheological properties depending on temperature on some of these viscosifiers performances on drilling fluids formulations and applications however, some of these studies examined the effect of these viscosifiers on rheological properties in isolation at different reservoir conditions; while others have studied the effect of different viscosifiers on rheological properties by combining the viscosifiers. For instance, Omohimoria and Falade (2017) compared imported bentonite (Wyoming) with local bentonite ((Afuze). Ahmed et al (2018) studied water-based bentonite drilling mud modified with iron oxide nanoparticles (nanoFe_2O_3). This paper is aimed at studying the effect of hydroxyethyl cellulose, local bentonite, and local cassava starch to determine the rheological properties at different temperatures (80 to 190 ^oF). It was observed that imported hydroxyethylcellulose, local bentonite, and cassava starch are rheological enhancers in water-based drilling mud.

MATERIALS AND METHOD

The materials and equipment used are listed in Tables 2.1 and 2.2.

Table 2.1: List of Materials Used

Item	Material	Function
1	Freshwater	The material used for mixing cement slurry
2	Hydroxyethyl Cellulose	The imported additive used as a rheological enhancer in drilling fluid and cement slurry
3	Bentonite	The imported additive used as a rheological enhancer in drilling fluid and cement slurry
4	Cassava Starch	The local additive used as a rheological enhancer in drilling fluid and cement slurry
5	Barite	Weighing agent

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Table 2.2: List of Equipment Used

Item	Equipment/Apparatus	Type/Model	Function
1	Hamilton Beach Mixer	Model 7000 	Constant Speed Mixer provides variable speed mixing from 100 to 21,000 no-load RPM with two preset constant speeds of 4,000 and 12,000 no-load RPM
2	Mud balance	Fann model 140 	A device used to measure the density of cement slurry
3	Viscometer	Chandler model 3530 	Used to measure the viscosity and gel strength of cement slurry.
4	Weighing balance	MT-2000 	This device is used for reading the weights of measured materials. Balances shall be accurate to +/-0.01% for measurements made at 10g or more and to +/-1% for measurements made at less than 10g

Drilling fluid formulations are selected based on well objectives and requirements. For the purpose of this study, Table 2.3 shows water-based mud formulations used in conducting the required experimental tests under different temperatures ranging from 80 ^oF – 190 ^oF.

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Table 2.3: Water Based Mud Formulations at different concentrations of Viscosifier

S/N	% Additives	Values (g)	Constant Freshwater values (g)	Weight of Barite (g)	Total Volume (ml)
1	**0.0**	0.00 (Control)	303.93	46.07	**350.00**
2	**0.5**	1.75	303.93	44.32	**350.00**
3	**1.0**	3.50	303.93	42.57	**350.00**
4	**1.5**	5.25	303.93	40.82	**350.00**
5	**2.0**	7.00	303.93	39.07	**350.00**

3. Results And Discussions

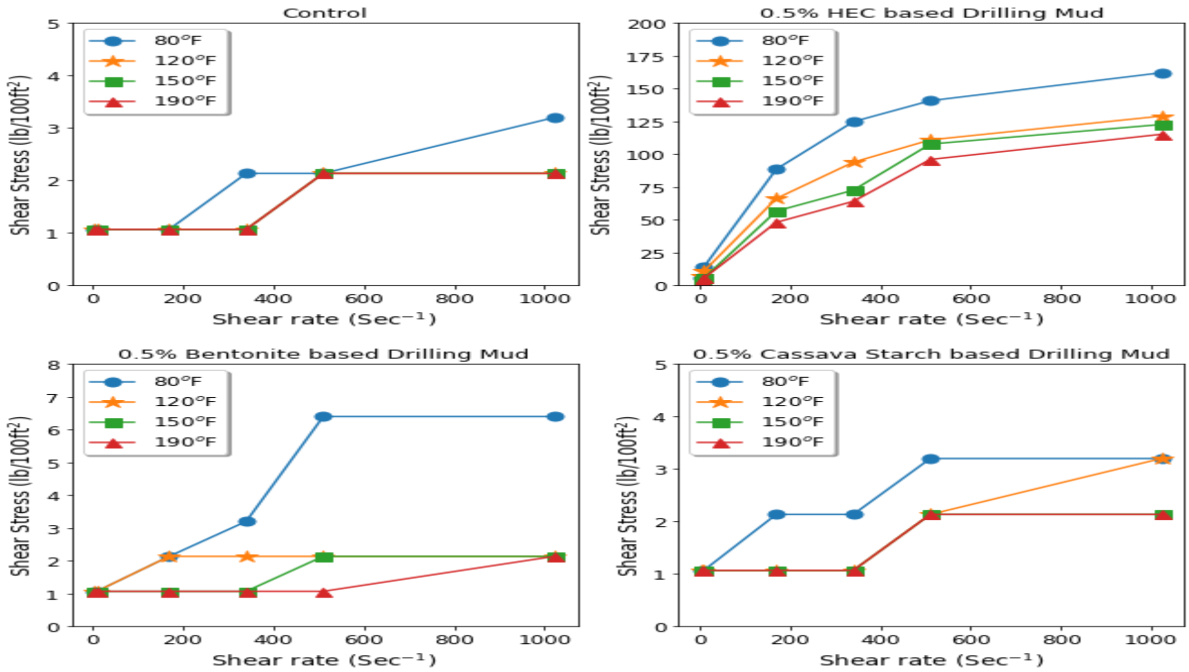

Figure 3.1: Shear Stress against Stress Rate for Drilling Mud with 0.5% Starch Concentration at Different Temperature

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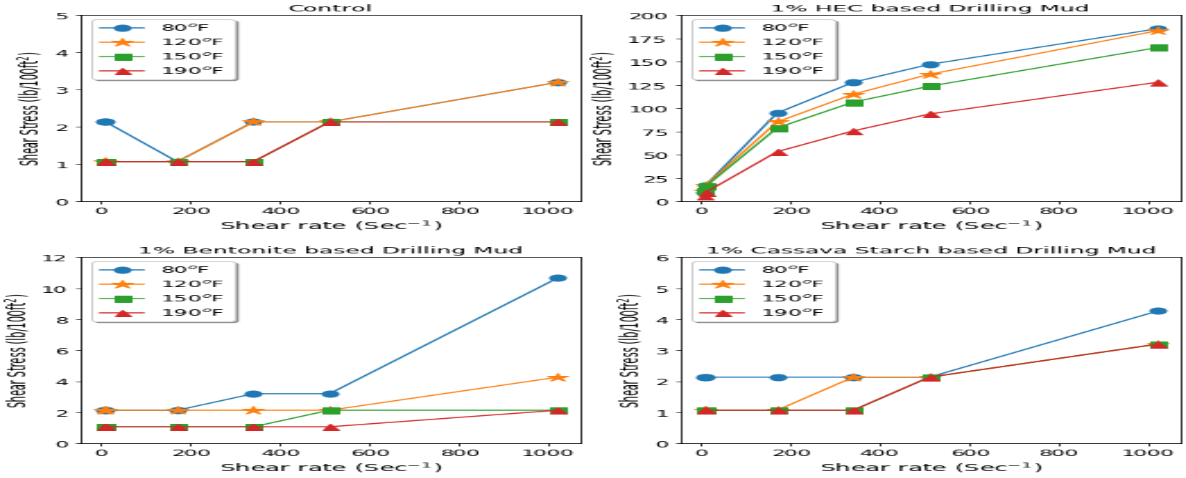

Figure 3.2: Shear Stress against Stress Rate for Drilling Mud with 1% various Viscosifiers Concentration at Different Temperature

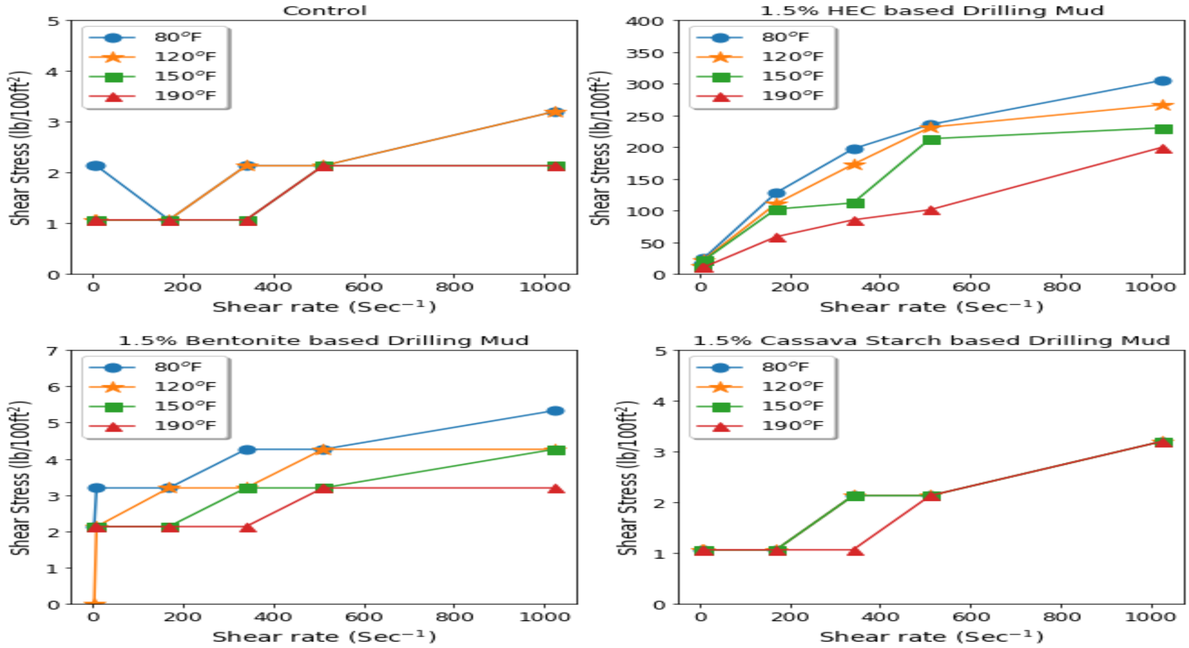

Figure 3.3: Shear Stress against Stress Rate3for Drilling Mud with 1.5% Various Viscosifiers Concentration at Different Temperature

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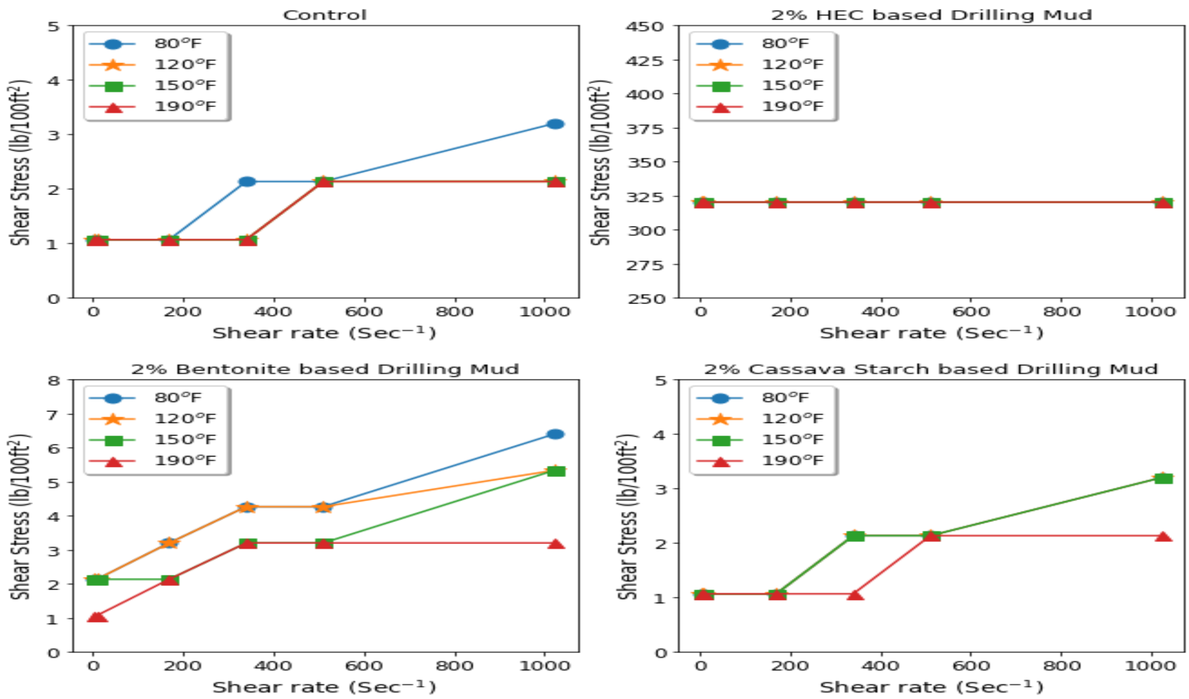

Figure 3.4: Shear Stress against Stress Rate for Drilling Mud with 2% Various Viscosifiers Concentration at Different Temperature

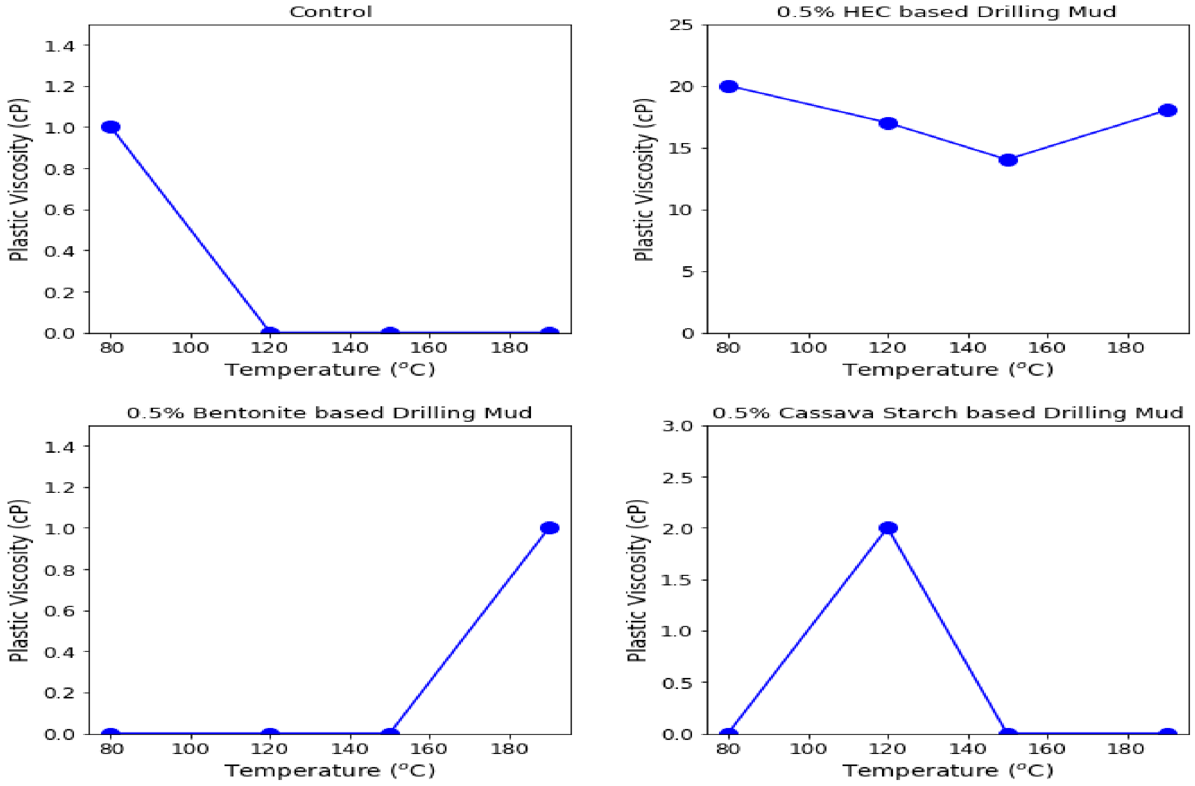

Figure 3.5: Temperature effect on the Plastic Viscosity of Drilling Mud at 0.5% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

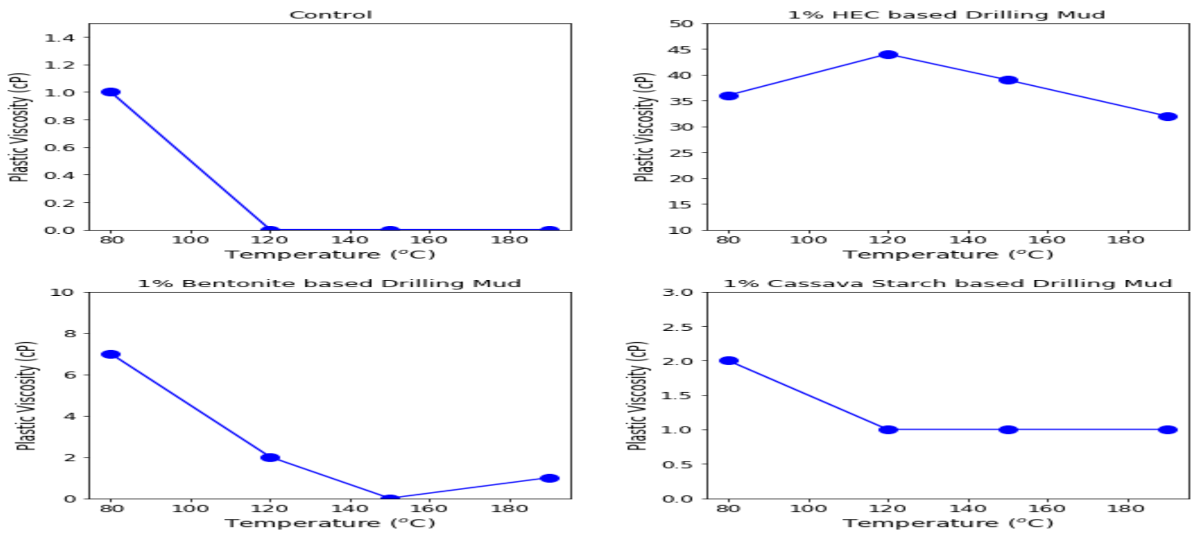

Figure 3.6: Temperature effect on the Plastic Viscosity of Drilling mud at 1% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

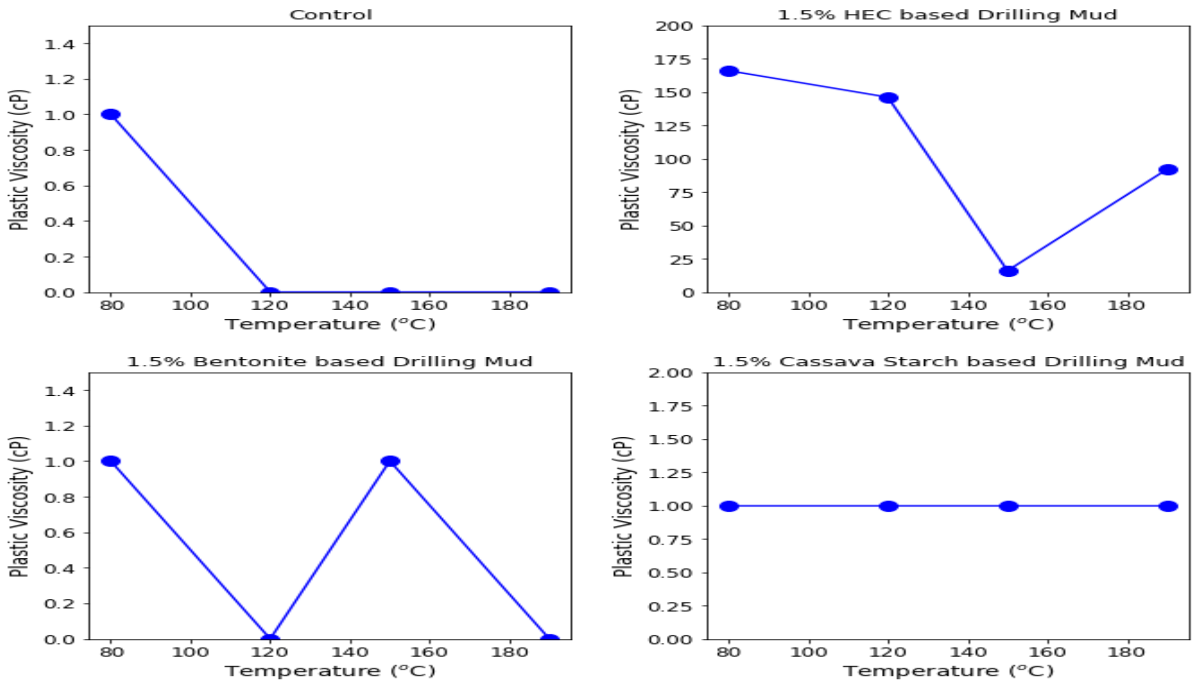

Figure 3.7: Temperature effect on the Plastic Viscosity of Drilling Mud at 1.5% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

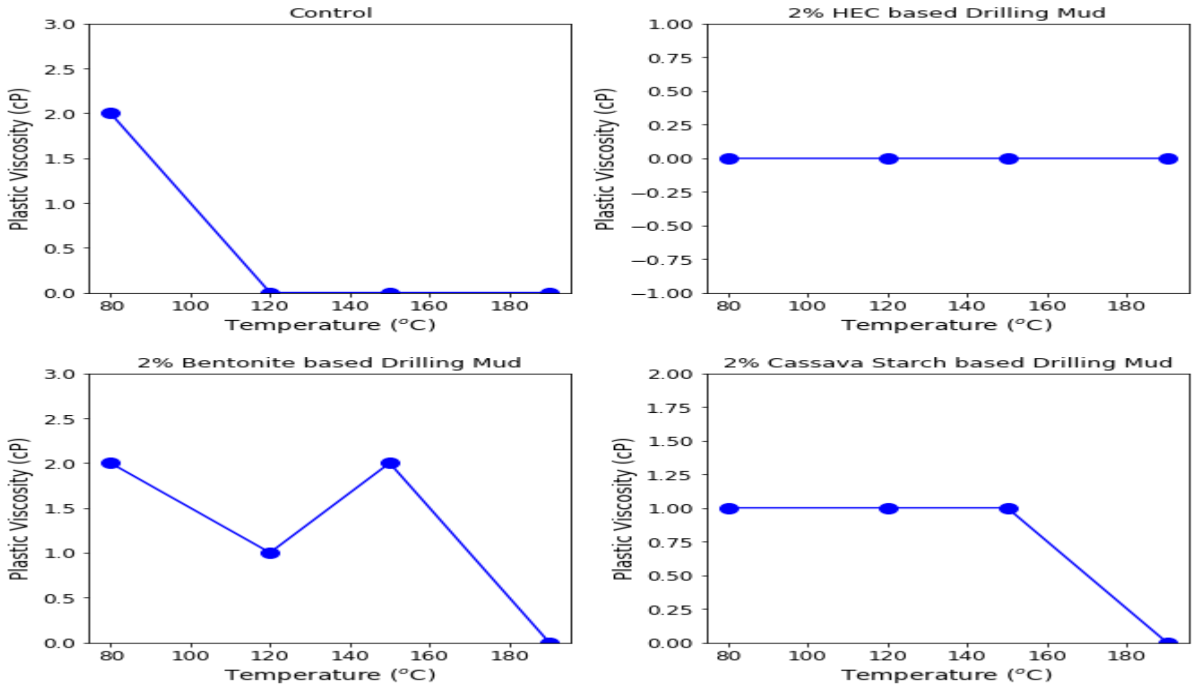

Figure 3.8: Temperature effect on the Plastic Viscosity of Drilling Mud at 2% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

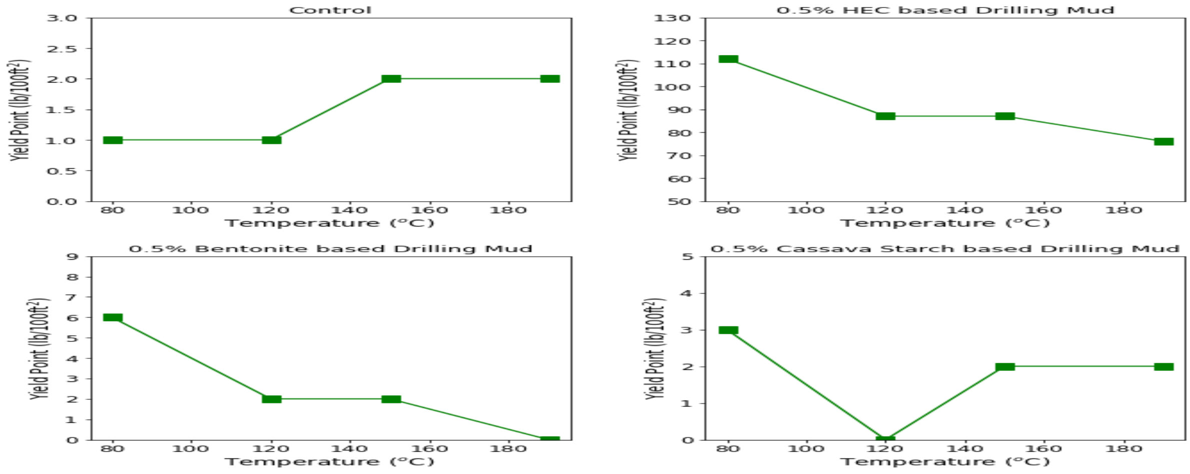

Figure 3.9: Temperature effect on the Yield Point of Drilling Mud at 0.5% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

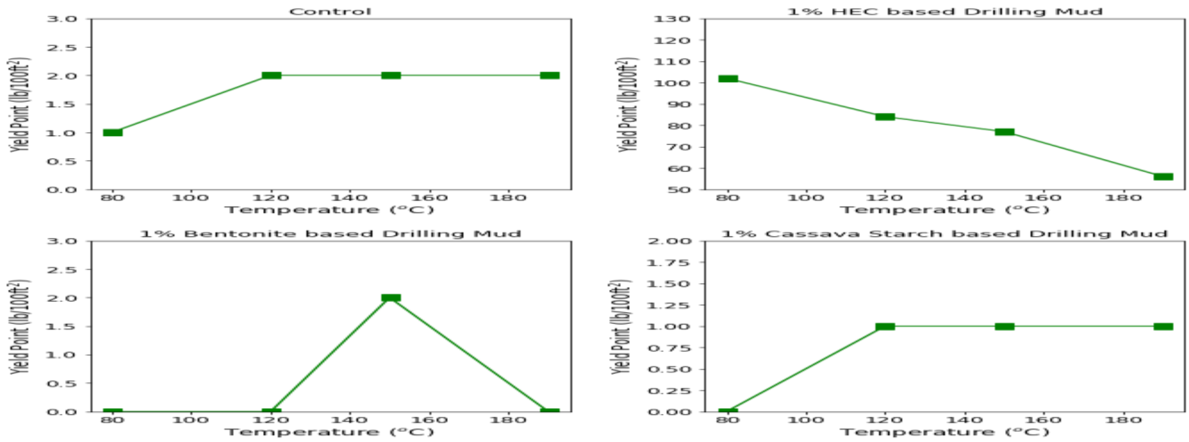

Figure 3.10: Temperature effect on the Yield Point of Drilling Mud at 1% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

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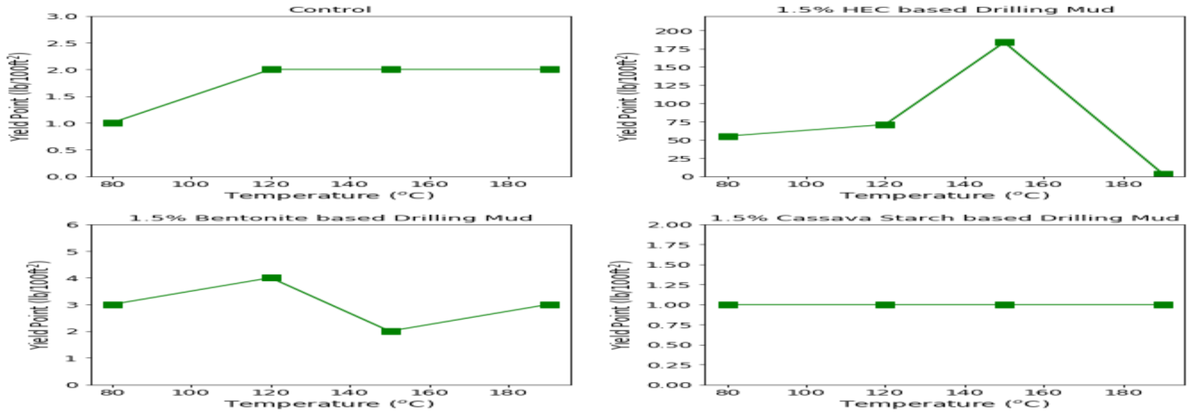

Figure 3.11: Temperature effect on the Yield Point of Drilling Mud at 1.5% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

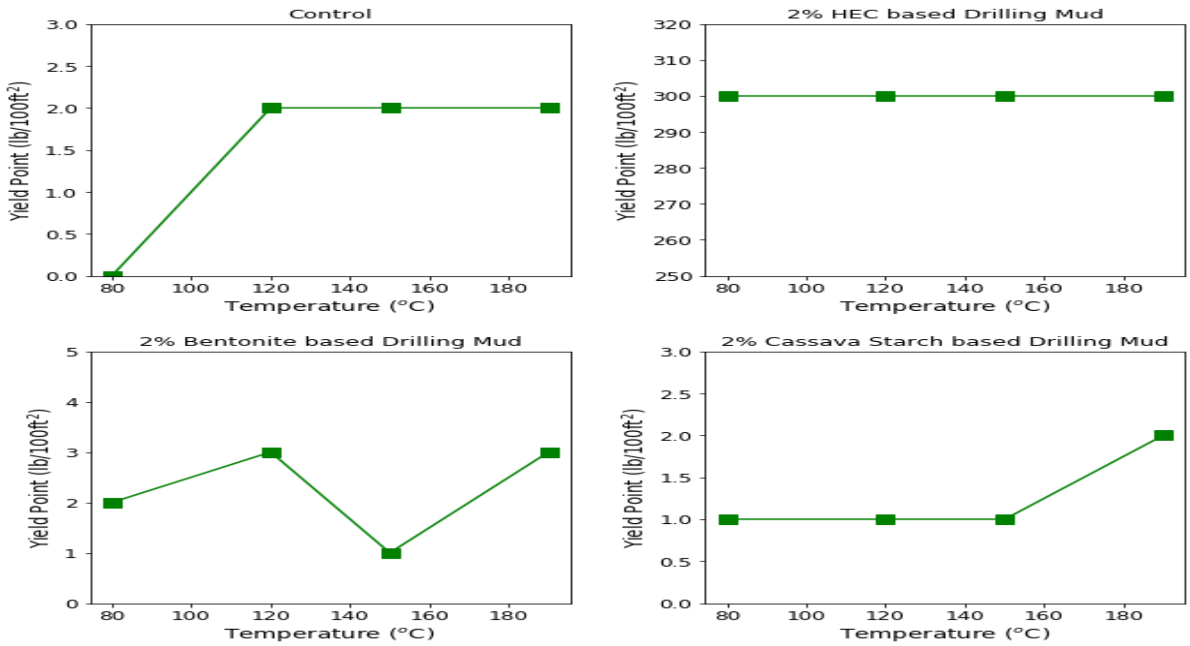

Figure 3.12: Temperature effect on the Yield Point of Drilling Mud at 2% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

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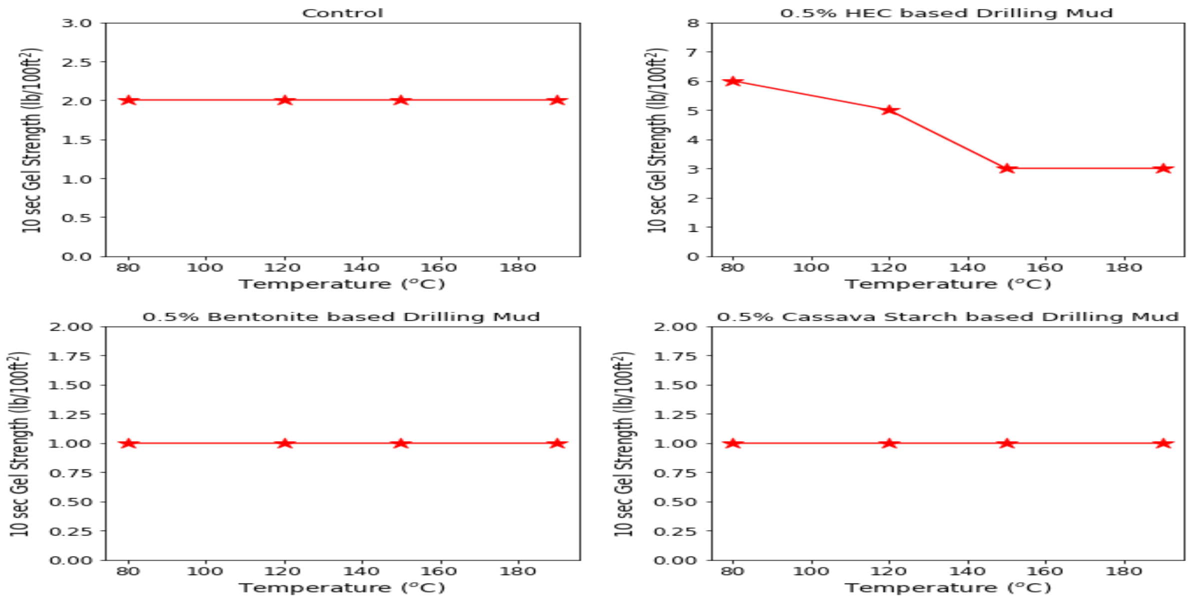

Figure 3.13: Temperature effect on the 10-sec Gel Strength of Drilling Mud at 0.5% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

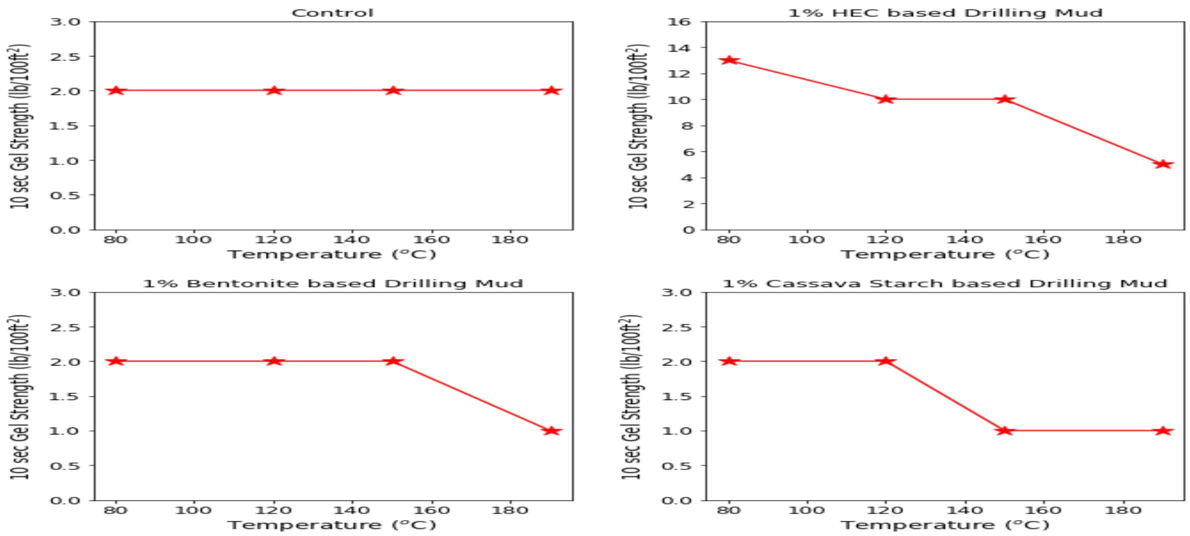

Figure 3.14: Temperature effect on the 10-sec Gel Strength of Drilling Mud at 1% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

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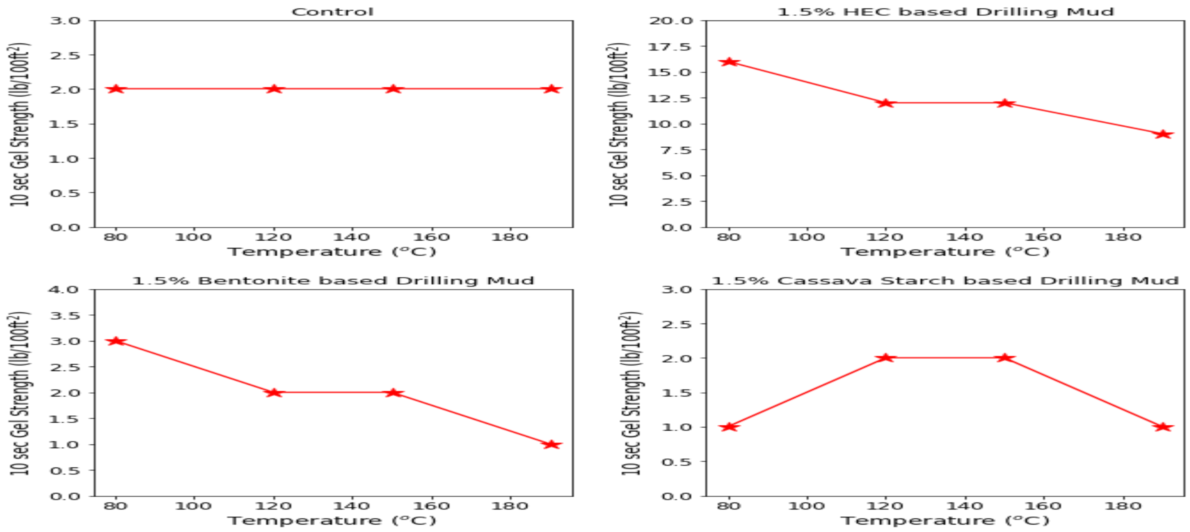

Figure 3.15: Temperature effect on the 10-sec Gel Strength of Drilling Mud at 1.5% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

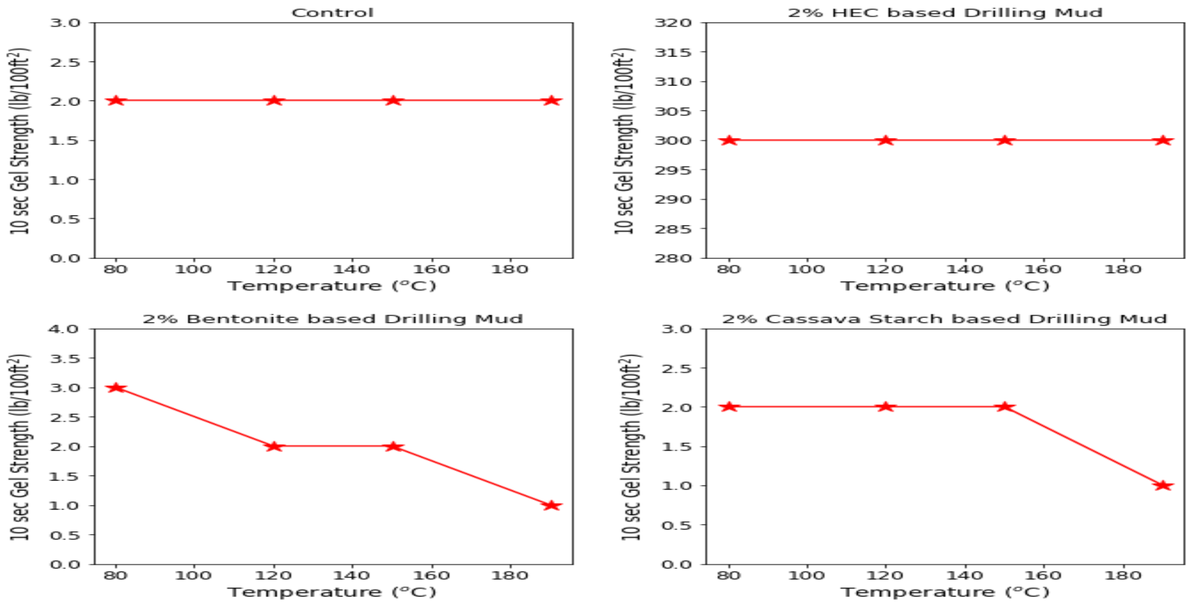

Figure 3.16: Temperature effect on the 10-sec Gel Strength of Drilling Mud at 2% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

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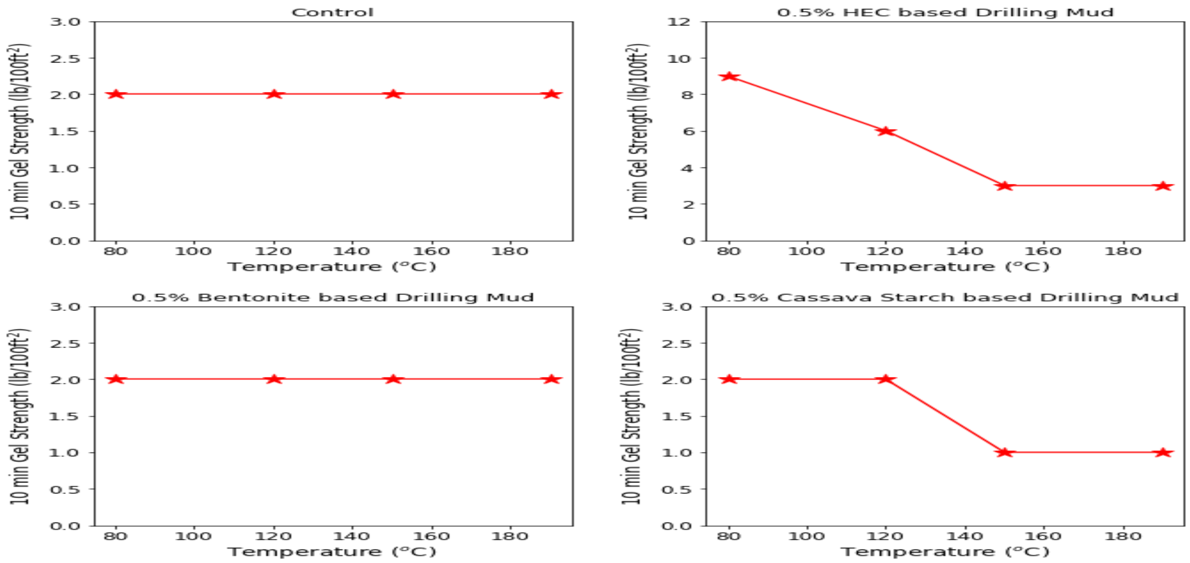

Figure 3.17: Temperature effect on the 10 min Gel Strength of Drilling Mud at 0.5% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

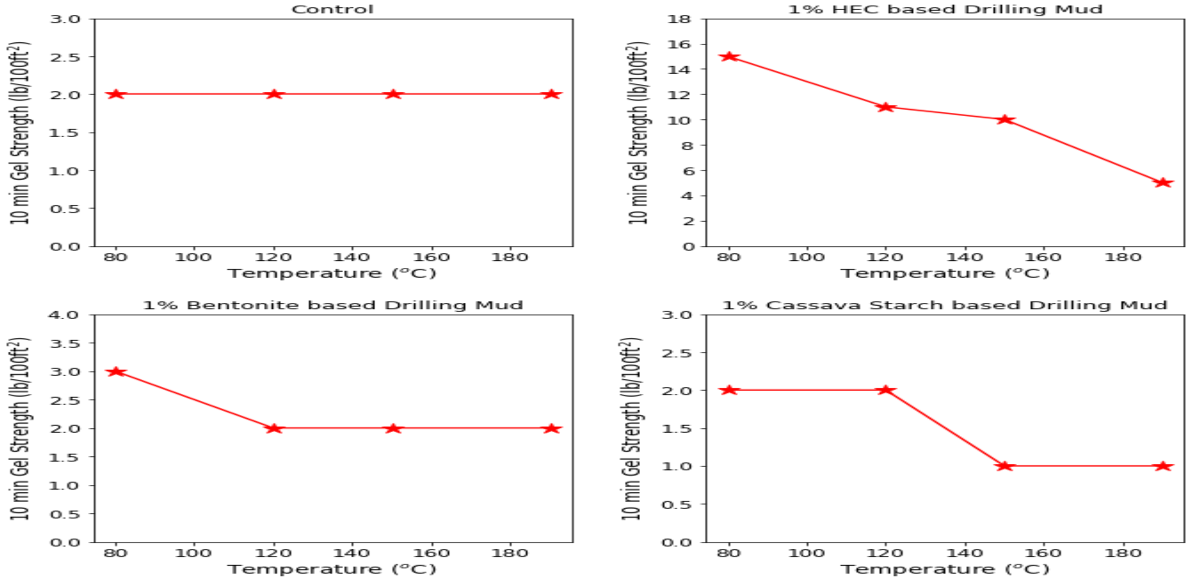

Figure 3.18: Temperature effect on the 10 min Gel Strength of Drilling Mud at 1% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

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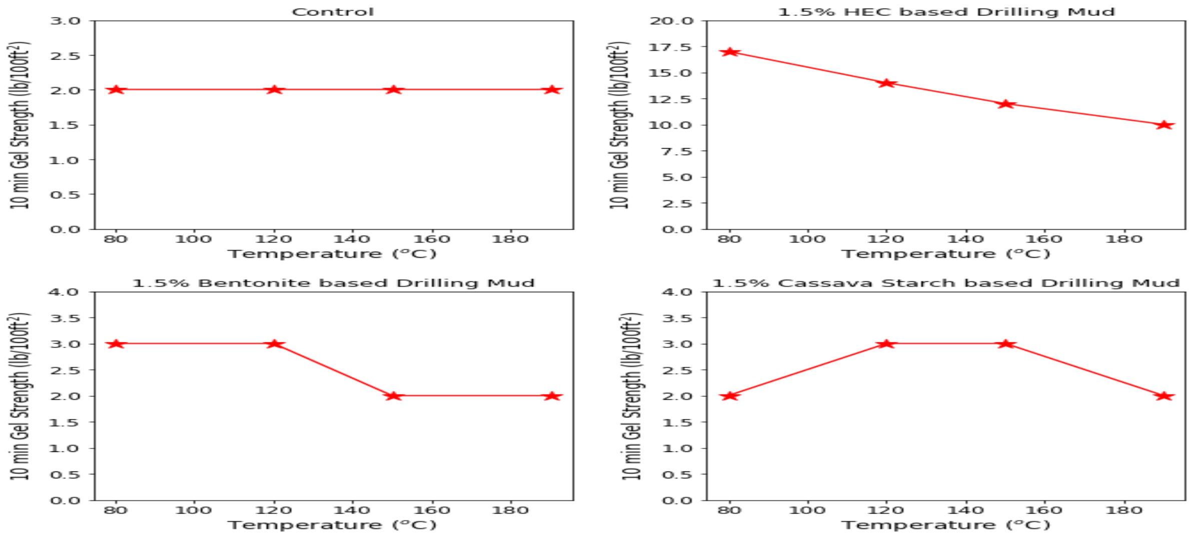

Figure 3.19: Temperature effect on the 10 min Gel Strength of Drilling Mud at 1.5% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

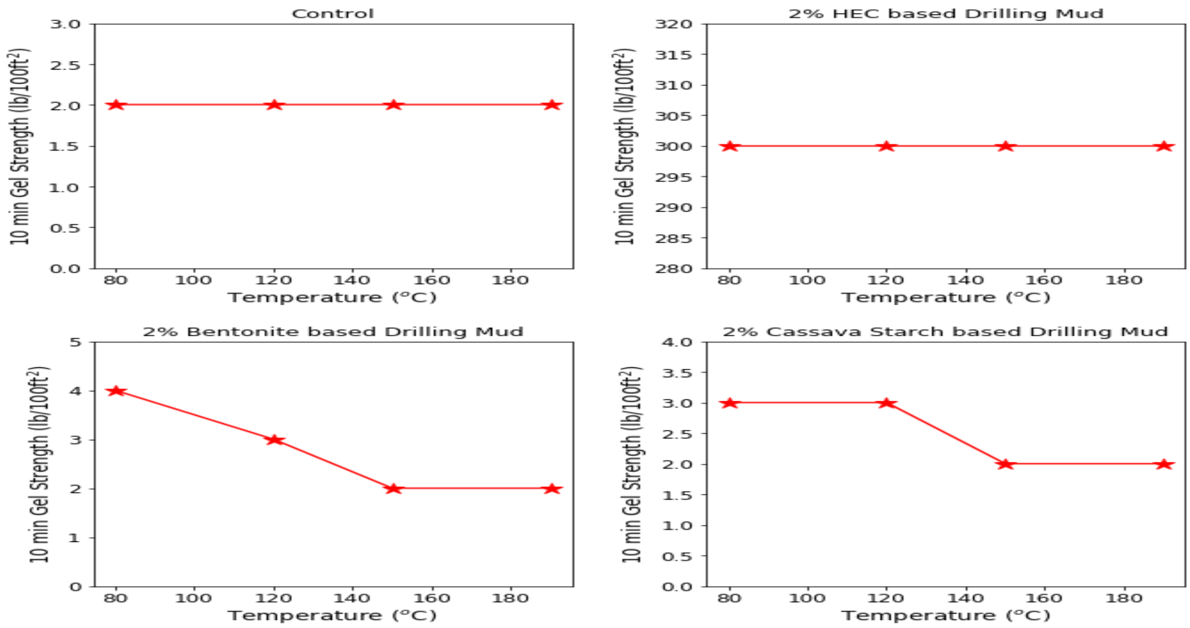

Figure 3.20: Temperature effect on the 10 min Gel Strength of Drilling Mud at 2% concentration of Imported Hydroxyethyl Cellulose, Bentonite, Local Cassava Starch

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DISCUSSION

The section focuses on the various aspects of the study however, it is segmented based on the experimental results. The rheological properties of hydroxyethyl cellulose, local bentonite, and local cassava starch-based drilling fluids were investigated with the aid of viscometer as shown in Table 2.2 and it was illustrated in Figures 3.1 to .3.4. It was observed that the rheological properties of hydroxyethyl cellulose, local bentonite, and local cassava starch-based drilling fluid were affected by the rotational speed and as well as the incremental increase of viscosifiers concentrations for both drilling fluids. For HEC based drilling fluid, the dial readings increased linearly with an increase in concentrations which is in line with the findings of Anjuman, *et al*., (2012). The same trend was observed for bentonite and cassava starch-based drilling fluids. However, the rheological properties of hydroxyethyl cellulose-based drilling fluid performed better than bentonite and cassava starch-based drilling fluids. The low rheological properties of the cassava starch-based drilling fluid may be associated with the kind of cultivar used because Harry *et al*., (2016b) stated that there are over forty cassava cultivars that are grouped as bitter and sweet and the authors stated that the bitter cultivars content cyanohydrins content which is the contributing factor to the high rheological performance of cassava starch. This is also in line with the findings of Ademiluyi *et al.* (2011) which states cassava starch with the highest amylose content and high water absorption capacity produced drilling fluid with higher viscosity and lower fluid loss. Furthermore, Drinah (2012), affirmed that cassava has approximately 150 species depending on their physical and chemical properties like most natural material would be influenced by genetic and site factors as well as the processing procedures; a period of storage would also affect the cassava starch because it is biodegradable. The high increase in the rheological properties of hydroxyethyl cellulose indicates that more energy will be required to make the drilling fluid.

Effect of Temperature on Shear Stress and Shear Rate Graph for Drilling Fluid with Different Imported Hydroxyethyl Cellulose, Local Bentonite, and Local Cassava Starch

The graphs depict the effect of temperature on shear stress and a shear rate of 0.5 %, 1.0 %, 1.5 %, and 2.0 % concentrations of hydroxyethyl cellulose, local bentonite, and local cassava starch-based drilling fluids. It was observed that shear stress decreased will correspond decrease in shear rate and also shear stress and the shear rate decreased with an increase in temperature. It then implies that the drilling fluids are shear-thinning meaning the flow of the drilling fluids does not flow until shear stress exceeded the critical values known as yield point and at a point shear stress and shear rate become proportional to increasing temperatures. However, the flow of the drilling fluid follows the pattern of Bingham plastic behavior which is general findings made by other researchers.

Effect of Temperature on the Plastic Viscosity of the Drilling Fluid with Imported Hydroxyethylcellulose, Local Bentonite, and Local Cassava Starch

The plastic viscosities were determined at different temperatures ranging from 80-190 °F to the shear stress/shear rate relationship for hydroxyethylcellulose, local bentonite, and local cassava starch-based drilling fluids as shown in Figures 3.5 to 3.8. It was observed that the

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plastic viscosities of the drilling fluids prepared with hydroxyethyl cellulose are higher than that of drilling fluids prepared with bentonite and cassava starch. However, the results obtained showed that incremental concentration of hydroxyethyl cellulose to water-based drilling fluid increased plastic viscosity which was also the findings of Salaheldin, (2019) that states that the addition of micronized starch to water-based drilling fluid increased the plastic viscosity by 25% whereas upon the incremental concentration of bentonite and cassava starch to water-based drilling fluid there was insignificant increase meaning that the cassava starch cultivar lack the hole cleaning ability and this could be as a result of less amount of amylose component in the cassava starch cultivar which the controlling effect of the gelling behavior since gelling is the result of the association of the linear chain molecules, (Ademiluyi *et al.*, 2011). Also, the low plastic viscosity of bentonite should be as a result of the low cation exchange capacity of montmorillonite phenomenon, that is, it is calcium ion (Ca^{2+}) based and that is the contributing factor in terms of its capacity for swelling, thixotropic, and adsorption (Grim, 1962; Ainsworth, *et al.*, 1994; Hijran, *et al.*, 2018), hence, hole cleaning with this bentonite-based water-based drilling fluid will be ineffective. Furthermore, the plastic viscosity of hydroxyethyl cellulose, bentonite, and cassava starch-based drilling fluids decreased with an increase in temperature (80 ^{o}F to 190 ^{o}F) meaning the drilling fluids exhibited shear thinning behavior. However, upon 2.0 % concentration of hydroxyethyl cellulose, it was observed that the plastic viscosity reduced to zero reason being that the 300 rpm was beyond the dial reading value and this is not good in the drilling operation, (Ghulam, *et al.*, 2013).

Effect of Temperature on the Yield Point and Gel Strength of the Drilling Mud with Imported Hydroxyethylcellulose, Bentonite, and Local Cassava Starch

To examine the effect of temperature on yield point and gel strength, water-based drilling fluids were prepared upon 0.5 %, 1.0 %, 1.5 %, and 20 % respectively of hydroxyethyl cellulose, bentonite, and cassava starch, and results were illustrated in Figures 3.9 to 3.12 and 3.13to 3.20. Static gel strength is an important factor related to annular fluid migration. It is a measure of the attractive forces between the particles in a fluid under static or non-flow conditions. Conversely, yield strength is an indication of the attractive forces under flowing conditions. Upon 0.5 %, 1.0 %, and 1.5 % concentrations of hydroxyethyl cellulose, bentonite, and local cassava starch, it was observed that the yield points, 10 sec and 10 min gel strength had flat gels and it is also referred to as low-flat meaning the drilling fluids thixotropic forming gelled structures when stagnant and liquefying when sheared and it is desirable in drilling operations because the drilling fluids remain fluidity while static. Although, hydroxyethyl cellulose-based drilling fluid exhibited progressive or high-gel which is undesirable meaning the drilling fluid will not be fluidity with time if left static in the hole, and then more energy will be required to continue circulation and that can lead to fracturing the hole especially within a fragile zone. Whereas, in the case of bentonite and cassava starch-based drilling fluids retained its flat-gel meaning it is desirable in drilling operations. However, if gel values are too low, barite sag or solids settling is likely to occur meaning that the drilling mud will not meet the task of suspending the ability of the cuttings and carrying capacity.

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CONCLUSION

The study was able to achieve its targeted objectives in formulating the viscosifiers; hydroxyethylcellulose, bentonite as well as local cassava starch. These viscosifiers produced improved the rheological properties of drilling fluids and cement slurries hence, based on the rheological studies, the following conclusion were made;

1. The hydroxyethyl cellulose-based drilling fluid and cement slurry displayed improved rheological properties from 0.5 % to 1.5 % concentrations and reached its trench hold at 2.0 %;

2. As the temperature increases from 80 ^oF to 190 ^oF there was a linearly decrease of rheological properties of hydroxyethyl cellulose-based drilling and cement slurry;

3. The bentonite and cassava starch-based drilling fluids displayed improved rheological properties from 0.5 % to 1 % concentrations whereas at 1.5 % and 2.0 % concentrations there was inconsistency in the rheological properties.

Based on the analysis carried out, further studies are recommended in the following areas. The government should encourage the production and commercialization of local cassava starch and bentonite having known that it enhances rheological properties.

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