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Improving the Rheological and Filtration properties of an Invert Emulsion Mud Using a Locally Sourced Modified Polymer

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Abstract: *Drilling fluid is designed for easy to use, cost effective and environmentally friendly. Several studies have been carried out on the use of local materials such as starch as suitable substitute for imported additives. Due to this short coming resulting from the use of native starch, the potatoes starch was chemically modified using the process of graft copolymerization, before being investigated as an additive for treatment of invert emulsion drilling. Three mud samples labelled (Base fluid, Copolymer 1 and Copolymer 2) were prepared and diesel labelled Base fluid served as control. Varying concentration of additives (1.0 and 2.0 g) were used at added to the different mud samples and laboratory study was carried out using the API Recommended Practice at varying temperature. This study is aimed at improving the properties of an invert emulsion mud using chemically modified locally sourced pomoea batatas as additive*

Keywords*: Methyl Acrylate; invert Emulsion drilling fluid; High Pressure High Temperature Sweet Potato starch, Graft copolymer*

I. INTRODUCTION

The use of drilling fluids is very important in the process of rotary drilling. The American Petroleum Institute (API) defined drilling fluid as a circulating fluid used in rotary drilling to perform any or all of the various functions required in drilling operations (Fink 2011). During the drilling process, drilling fluids can be likening to the blood in the human physical structure as the success of the drilling operation relays on it (Nasser et al., 2013). Drilling fluids consist of suspensions of clay particles in water or oil. The drilling fluids should provide the essential functions, such as cooling and lubricating the bit, removing cutting and releasing same at the surface, providing wellbore stability, transfer the hydraulic power from the surface to downhole motors. They are design while considering some factors such as the formation temperature, and shale induced problems. In order to enhance the overall performance of these fluids, chemical additives are added in small amount to perform one or more specific functions.

Several additives are used in the drilling industry These chemical additives are added to drilling fluids in small amount in order to enhance its performance by changing the properties and mud composition. Oil or gas wells which have static reservoir pressure greater than 10000 psi and temperature above 300°F are classified as High-Pressure High-Temperature (HPHT) wells (Smithson T., 2016). Not only is it necessary for a drilling fluid to have an appropriate high temperature transfer and flow properties. There is need for it to be environmentally friendly (Gupta and Walker, 2007). While drilling this types of wells, specially formulated muds are needed to meet the critical downhole conditions encountered.

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One of such additive is the use of polymer. Polymers such as starch have been used extensively for over fifty years, as an additive in controlling the filtration properties of a drilling fluid. Native starch have been used due to its abundance, low cost, and biodegradability nature (Ghazali, 2015)

Akintola and Isehunwa (2015) examined the effect of temperature and aging on water base mud treated with native starches prepared from maize and cassava. But due to the short coming of the use of native starch, they have to be chemically modified in order to improve its solubility and thermal stability, as well as its resistance to bacterial attack.

There are several methods of modification of starches, this can be done by pregelatinization oxidization, thermal treatment ,etherification, and graft copolymerization The use of Pre-Gelatinized Starch (PGS) as the fluid loss control agent in the Non Damaging Drilling Fluid (NDDF) has been demonstrated by Talukdar and Gogoi (2015) used the Pre-Gelatinized Starch (PGS). The process of carboxylation of starches have been carried out on different starches such as corn (Khalil et al., 1990) wheat (Thewlis, 1969), Corn starch waste (Yamauchi and Sasaki. 1992) . Athawale, *et al*.(1998) ; Singh (2007) in their studies stated that the grafting of starch with vinyl monomers seems to be the most effective method to introduce different functional groups into the polysaccharide and increase its molecular mass, thus achieving a tailored macromolecular architecture and performance as stated.

II. MATERIALS AND METHODS

2.1 Materials

The Sweet potatoes (Ipomoea batatas) was obtained from a local market in Ibadan Oyo State. Double Distil water, Analytical grade Acrylamide (AM), acetone, methanol, dichloromethane (DCM), ceric ammonium nitrate (CAN), N-methylacrylamide (NMA), acrylic acid (AA) and methylacrylate (MA). N, N-dimethylacrylamide (DMA) were purchased from Sigma Aldrich. Middle fraction of the vacuum distilled DMA and double distilled water were used in the synthesis. The Fann 35A Rheometer and the High Pressure High Temperature Filter press.were used to determine the mud samples rheological and fluid loss properties, respectively.

The processes of this study is divided into 2 stages. the first is the creation of the copolymer using graft copolymerization of starch extracted from sweet potato with acrylic monomers while the Second is the is the preparation of the invert emulsion and treating same in an invert emulsion according to the recommended standard

2.2 EXTRACTION OF STARCH PROCESS

20 grams potatoes tubers were cleaned (by washing to remove stone, seed and dirt), before Cutting into small sizes into a bowl distilled water was added this was allowed to stand for 48hours before crushing to remove impurities such as like fiber, protein and cell sap inside the crushed sweat potatoes paste by using a centrifuge sieve, After the potato starch mixture has been squeezed, the starch settled in the bottom of the bowl. The wet starch is allowed to dry in the open air for 72 hours before being stored in an air tight labelled container.

2.3 SYNTHESIS OF SWEET POTATOES STARCH

The methodology described by Viera et al. (2007) with slight modification was used to methylate the starch obtained from Sweet potato. 500g of the potatoes starch was initially mercerized using 100mL of 50% w/v solution of sodium hydroxide (NaOH) for 2hours at ambient temperature, after which the mixture was filtered to remove excess NaOH. 75mL of acetone and 3ml of dimethylsulfate (DMS) solution were then added to the mixture and allowed to stand for 5hours at 50^oC by shaking in a closed system, and the reaction mixture was changed hourly by filtering off the mixture (DMS + acetone). Finally, the mixture was neutralized with 100ml acetic acid at 10% v/v solution and filtered in a plate funnel and washed with three successive portions of acetone. The final product obtained was dried in an oven at 50^oC for 6hours and kept in a dessicator.

2.4 POLYMERIZATION OF METHYL ACRYLATE

300mL of methyl acrylate monomer was charged inside a 3-necked 1.5L batch reactor equipped with a mechanical stirrer, an inlet for Nitrogen gas and a temperature regulator. 10mL of acidified potassium permanganate ($KMnO_4$) was added to the monomer in the reactor as catalyst and homogenization occurred for 30mins. The reaction was allowed to proceed for 3hours at 90°C. 5mL of 0.1mol/dm^3 of hydroquinone was added to bring the reaction to a halt.

The reaction mixture was allowed to cool to room temperature. The final product was washed with methanol so as to remove the unreacted methyl acrylate, catalyst and other impurities. The final product was kept in a container for other application analysis.

2.5 GRAFTING OF POLY (METHYL ACRYLATE) UNTO STARCH BACKBONE

120g of extracted starch, 28mL acidified $KMnO_4$ were added in a 1.5L, 3-necked batch reactor. These were thoroughly stirred for 20mins with a mechanical stirrer. Then, 20g of the prepared poly (methyl acrylate) was added and the mixture was homogenized again for 5minutes in an inert environment under Nitrogen gas. The reaction was allowed to continue for 8hours. It was terminated by adding 6mL of 0.1M of hydroquinone with continuous stirring for 10minutes. The product obtained was allowed to cool to room temperature for 3mins and was washed with 200mL methanol to remove the unreacted PMA, starch and catalyst from the grafted fraction. The final product was dried with sodium sulphate (Na_2SO_4) and was kept in a closed container until the period of analysis.

2.6 GRAFTING PARAMETERS

The grafting percentage (GP) indicates the increase in weight of original polymer subjected to grafting with a monomer and the initial weight of backbone are calculated using the equations 10 and 2.0, respectively

$$Grafting\ Percentage = Weight\ of\ polymer\ grafted\ \times 100 \qquad 1.0$$

$$Initial\ weight\ of\ backbone = (W_1 - W_0)\ \times 100 \qquad 2.0$$

Where: $W_1 and\ W_0$ are the weights of the methylcellulose graft copolymer and the original methylcellulose, respectively.

2.7 GRAFTING EFFICIENCY (GE)

The Grafting efficiency and fraction of polymer which is grafted was calculated by applying the the equations 3.0 and 4.0, respectively :

$$Grafting\ Efficiency\ (\%G.E) = Weight\ of\ polymer\ grafted \times 100 \qquad 3.0$$

$$Weight\ of\ polymer\ grafted + Weight\ of\ homopolymer = \frac{(W_1 - W_0)}{(W_1 - W_0\ +\ W_2)} \times 100 \qquad 4.0$$

Where: $(W_1,\ W_0\ and\ W_2)$ are the weights of the methylcellulose graft copolymer, the original methylcellulose, and the homopolymer (polymethylacrylate), respectively.

The weight of homopolymer W_2 can be calculated by subtracting the amount of grafted polymer plus the amount of unreacted monomer from the initial amount of monomer.

2.8 PREPARATION OF THE INVERT EMULSION MUD

The materials used in the formulation of the invert emulsion were supplied by Mi Swaco. Port-Harcourt , Rivers State and the experiments were performed in the Petroleum Engineering Laboratory , University of Ibadan. The new copolymer was added to the invert emulsion drilling fluid to evaluate its effect on the sag performance. The new copolymer was obtained from graft copolymerization process of the sweet potatoes starch with poly (methyl acrylate) with a bulk density of 3–5 ppg and a pH of 9–11 at 10% solution. The new copolymer is soluble in oil and dispersible in water. The invert emulsion mud composition was prepared as present in the Table 1.0

2.9 DETERMINATION OF THE MUD SAMPLE PROPERTIES

The rheological properties (Plastic viscosity, Yield point, Apparent viscosity and gel strength after 10 seconds and 10 minutes of static gel time.)of the various mud samples were obtained using the Fann35A rheometer. The equations 5.0, 6.0 and 7.0 were used to determine the mud, Plastic viscosity ,Yield point, and Apparent viscosity, respectively.

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$$Pv = \theta_{600} - \theta_{300} \qquad 5.0$$

$$Yp = \theta_{300} - (\theta_{600} - \theta_{300}) \qquad 6.0$$

$$Av = \frac{\theta_{600}}{2.0} \qquad 7.0$$

To evaluate the effect of the copolymer on the invert emulsion drilling fluid, the mud density and electrical stability properties at ambient temperature, the rheological properties at a temperature range of (200–400 °F); and the filtration properties at 400 °F and 500 psi differential pressure were determined.

The drilling fluid preparation, the density and the electrical stability were measured for all the drilling fluid samples at room temperature using mud balance and emulsion stability tester, respectively. Rheological properties were obtained from the viscometer dial readings at different temperatures (200, 300 and 400 °F) and a pressure of 2000 psi.

Table1.0: The Invert Emulsion Mud Composition

Additives	Functions	Base fluid	Copolymer 1	Copolymer 2
Diesel(cm3)	Continuous phase	172	172	172
EZ-Mul	Emulsifier and oil-wetting agent	15	15	15
Invermul(g)	Primary emulsifier	11	11	11
Lime(g)	Contaminate remover	6	6	6
Geltone II (g)	Viscosifier	2	2	2
Water ((cm^3)	Dispersed phase	50	50	50
$CaCl_2$ (g)	Shale inhibitor	30	30	30
$CaCO_3$ (25 micron,g)	Bridging agent	30	30	30
RM-63(g)	Rheology Modifier	1	1	1
New Copolymer (g)	Rheology modifier and solid suspension	0	1	2
Barite (g)	Weighting material	560	560	560

III. RESULTS AND DISCUSSION

3.1 Effect of Co polymer on the Mud sample Rheological Properties

The results of the work in this study are hereby presented. The Figures 1.0 to 3.0 depicts the effect of the addition of the copolymer on the shear stress at different temperatures. Adding the copolymer increased the shear stress of the drilling fluid at a temperature greater than 300 °F. At a high shear rate (1020 S−1), the base fluid had a shear stress of 101 and 84 lb/100 ft^2 at 300 and 400 ^{0}F ,respectively, while at the same shear rate, the enhanced drilling fluid with the copolymer had a shear stress of 114 and 103 lb/100 ft^2 with 1.0g concentration and 123 and 112 lb/100 ft^2 with 2.0g concentration at 300 and 400 ◦F, respectively.

The Figures 4.0, 5.0 and 6.0, presents the result for the rheological properties of the drilling fluid samples. The rheological properties are seen to decreases as the temperature increases. In the Figure 4.0, the plastic viscosity was highest.at 200 °F also as the concentration of copolymer increased, the plastic viscosity increased . Then, at 300F, we see a drastic reduction in the Plastic Viscosity. The change was not so much as temperature increased from 300° F to 400°F.

From Figure 5.0, at 200 °F, the yield point was highest. And as the concentration of copolymer increased, the yield point increased also. Then, at 300 °F it was noted that a drastic reduction in the Yield Point. The change was not so much as temperature increased from 300° F to 400° F.

The apparent viscosity shown in the Figure 6.0 also shows a decrease in the apparent viscosity as temperature increases.

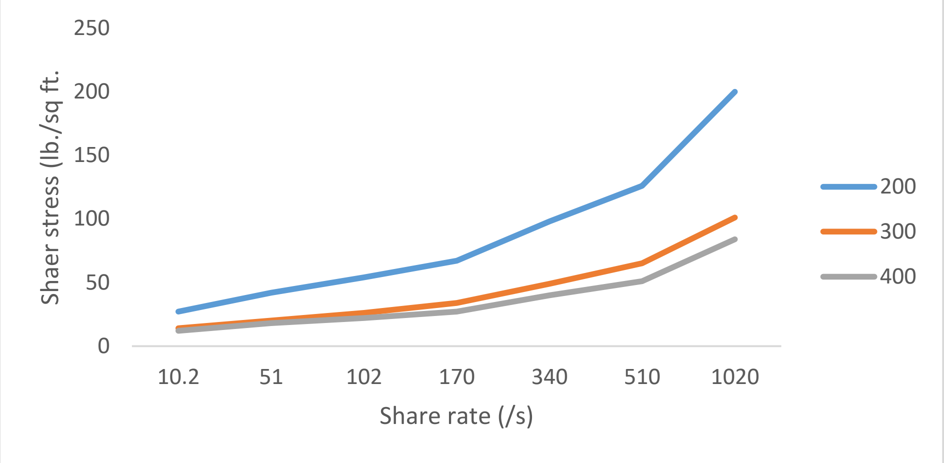

Figure 1.0:: Effect of Temperature on shear stress versus shear rate for base fluid

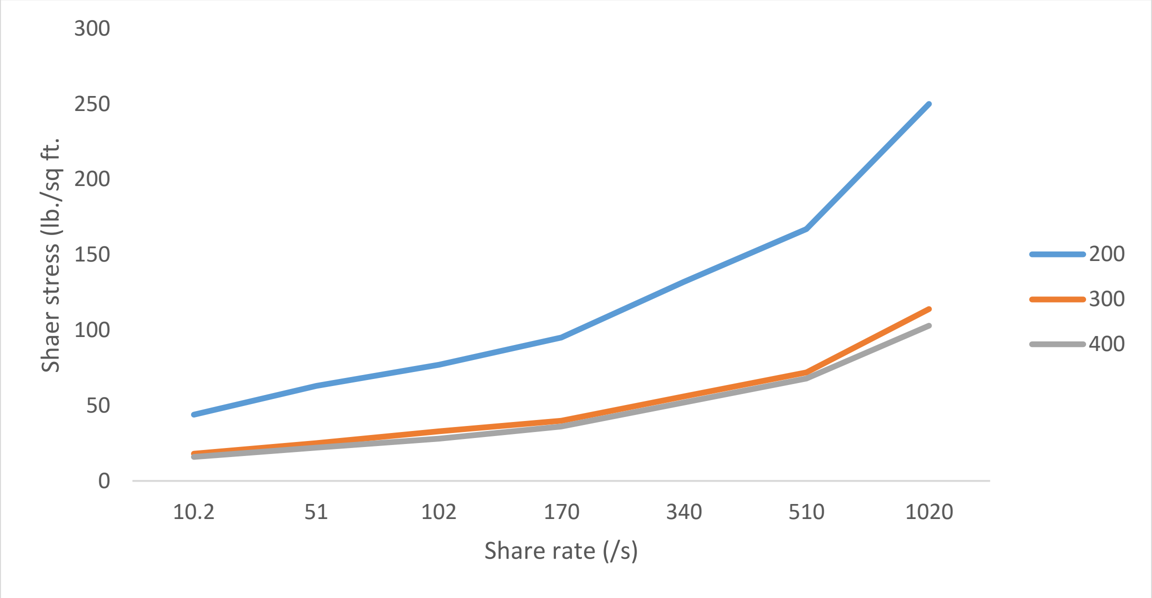

Figure 2.0:1 Effect of Temperature on shear stress versus shear rate for 1g of copolymer

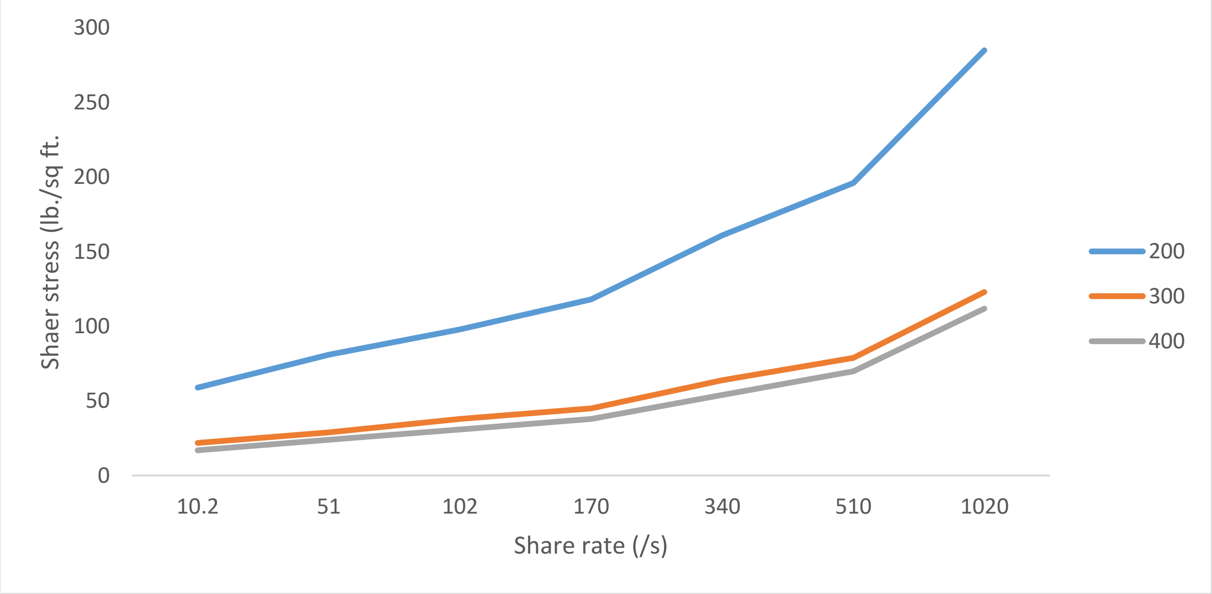

Figure 23.0 : Effect of temperature on shear stress versus shear rate for 2g of copolymer

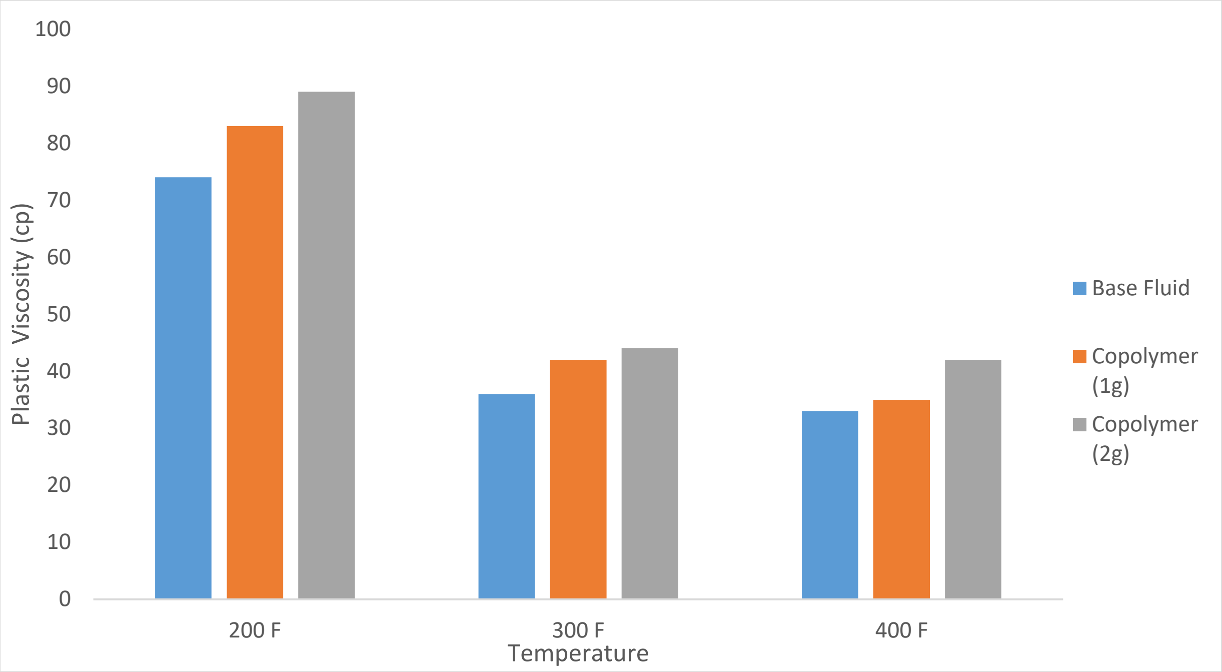

Figure 4.0: Effect of Varying concentration of the new Copolymer on Plastic viscosity at varying Temperatures

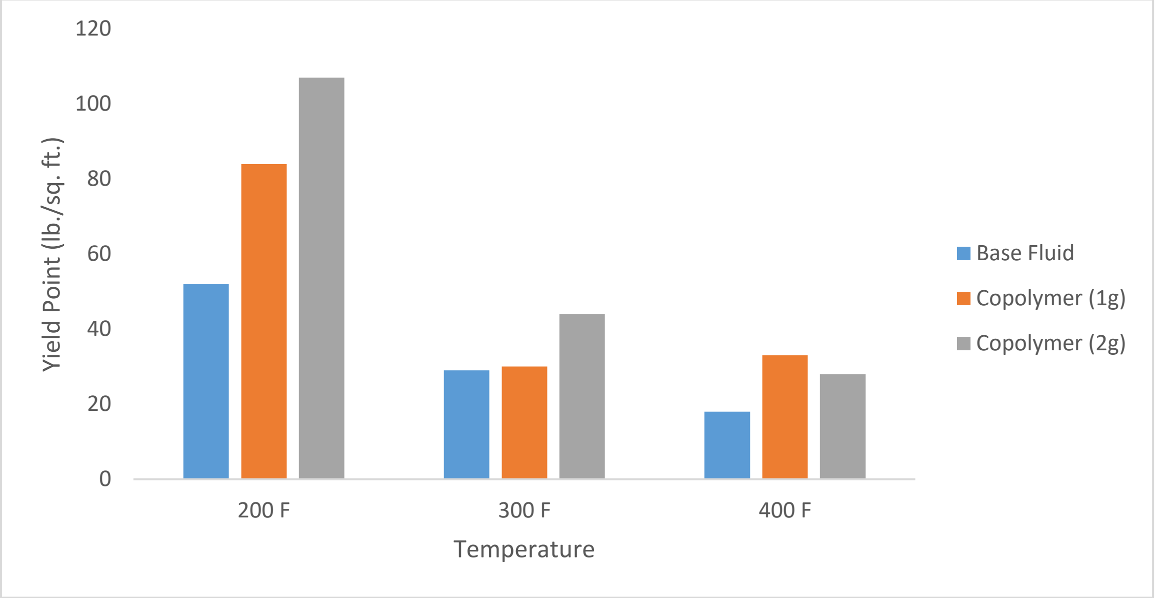

Figure 5.0: Effect of Varying concentration of the new Copolymer on Yield point at varying Temperatures

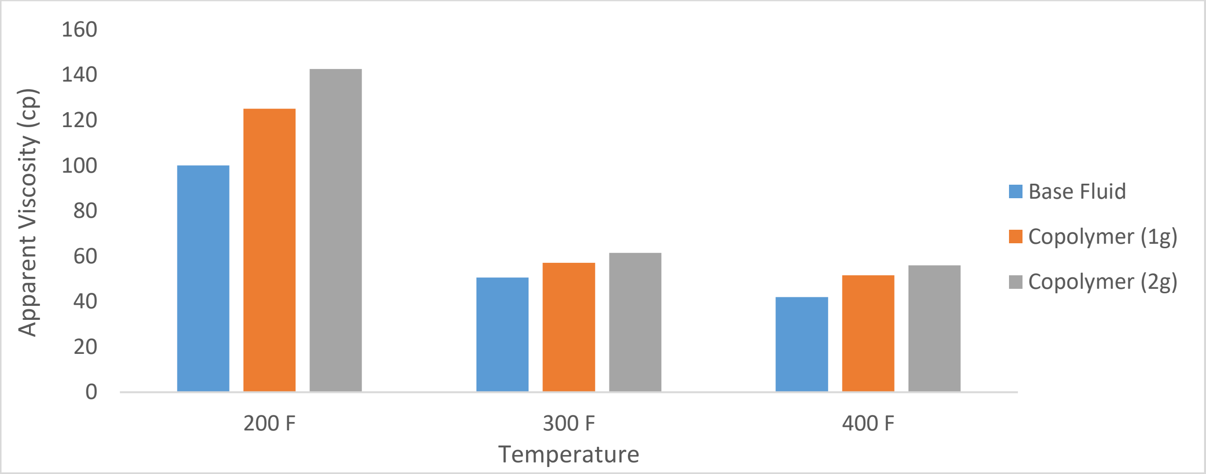

Figure 6.0: Effect of Varying concentration of the new Copolymer on Apparent viscosity at varying Temperatures

It was observed that the increase in the shear stress at higher shear rate indicates a better rheology at a higher temperature. The reduction in the shear stress, by increasing the temperature caused a loss of the suspension properties and indicates the settling of the solids from the fluid at a low shear rate. With the addition of the copolymer to the drilling fluid enhancing the mud shear stress at a different temperature. This result proves the importance of adding the copolymer to the drilling fluid to enhance the suspension property and prevent the sag.

3.2 Effect of Co polymer on the Mud sample Filtration Properties

The filtration test was conducted on all the drilling fluid samples with and without the copolymer under a static condition at a high temperature, 300^0 F and 400 ^{o}F, and differential pressure, 100 psi. with the Figures 7.0 and 8.0 showing the fluid loss properties of the mud samples. The results show that at 300^{o}F, the filtrate volume was 2.50cm for sample labelled base fluid but reduced to 2.40 cm^3 when the copolymer was added. But the concentration had no effect on the filtrate volume at that temperature. Also, at 400 ^{o}F, the filtrate volume after 30 minutes was 3.00cm^3 for sample labelled base fluid with no visible change was observed when 1.0g of the copolymer was added,. However, by increasing the concentration to 2.0g, the fluid loss decreased to 2.80 cm^3.

Under the same conditions, the filter cake thickness was reduced to become 1.60 mm, which reflects the stability of the weighting materials in the drilling mud after adding the copolymer. Whereas, in the case of the base mud, the solids precipitated and increased the thickness of the filter cake.

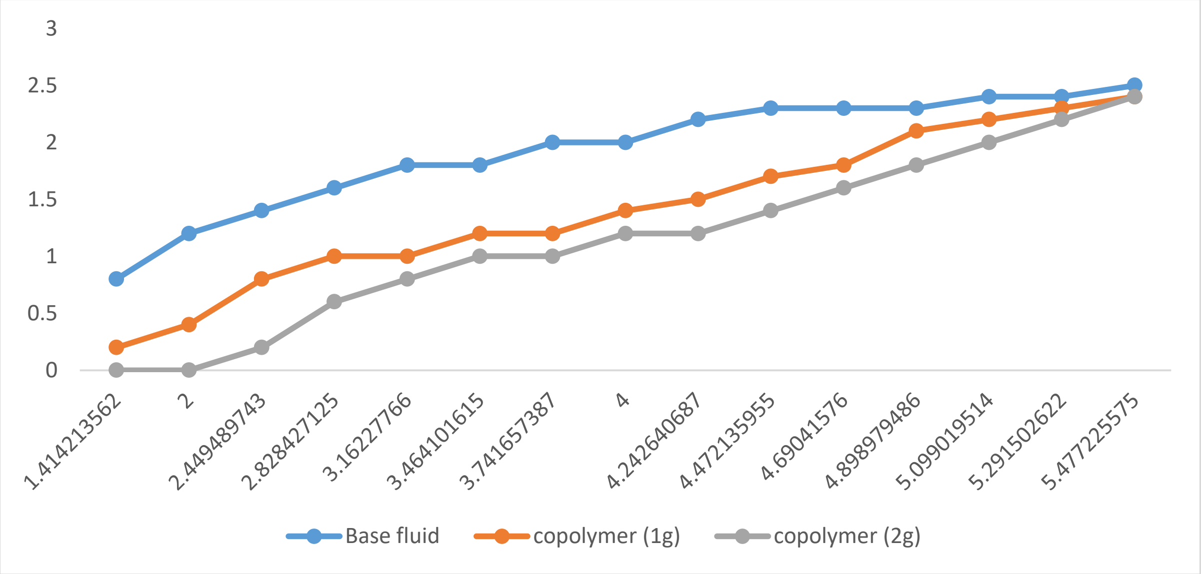

Figure 7.0: Filter loss at 100psi and 300°F

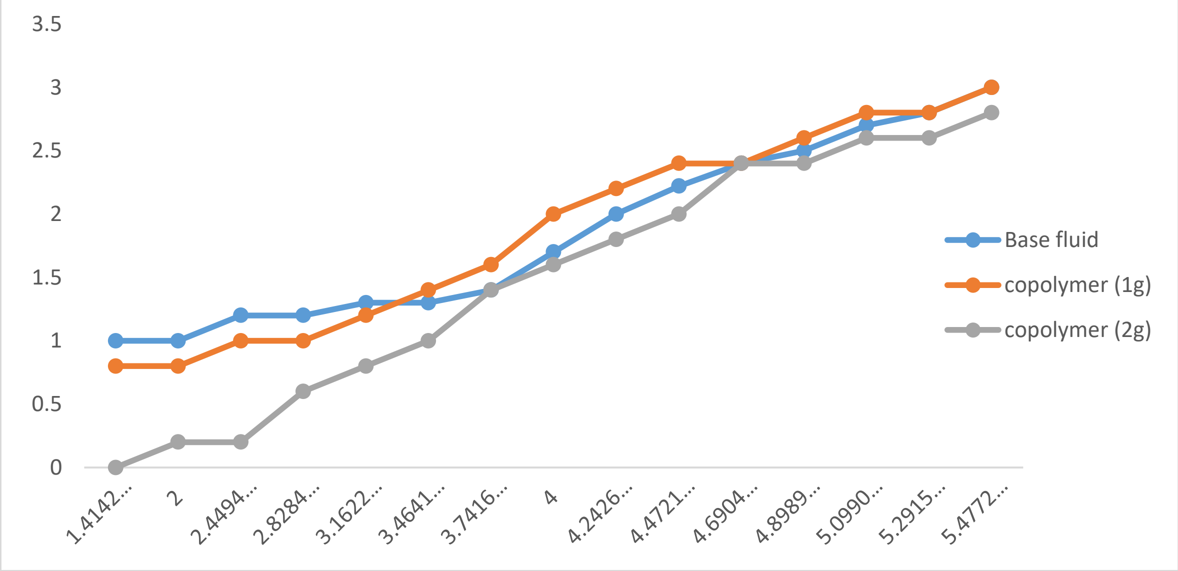

Figure 8.0: Filter loss at 100psi and 400°F

For the fluid loss, at 300°F, the filtrate volume was 2.50cm^3 for base fluid but reduced to 2.40 cm^3 when the copolymer was added. The concentration had no effect on the filtrate volume at this temperature. But as the temperature increased to 400 ◦F, the fluid loss after 30 minutes was 3.00cm^3 for the base fluid. The addition of 1g of the copolymer show no significant effect on the filtrate volume, however, by increasing the concentration to 2g, the fluid loss decreased to 2.80 cm^3. A decrease in the mud cake (1.60 mm) was observed, this reflects the stability of the weighting materials in the drilling mud after the addition of the copolymer. But that mud labelled base mud, had solids precipitated and increase in the thickness of the filter cake.

IV. CONCLUSION

The use of graft copolymer starch from sweet potaotes exhibited a positive effect on the properties of the invert mud emulsion. The concentration had no effect on the filtrate volume at 300°F. Addition of the copolymer improved the rheological properties of the drilling mud, as the concentration increased, the rheological properties were improved

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