Experimental Study of Shear Stress of Local and Imported Polymers in Oil Well Cementing Operations under Different Slurry Densities and Temperatures

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Abstract:  
A polymeric material is a primary additive used in cement slurry design to maximize viscosity, minimize fluid loss as well as free fluid in wellbore completions. Currently, different types of derivatized cellulose-based polymers are used in the petroleum industry as multifunctional additives in cement slurry to improve API properties such as rheology, fluid loss, free fluid and thickening time. Examples of such polymers are: Carboxymethylcellulose (CMC), Hydroxyethyl cellulose (HEC), Carboxymethyl- hydroxyethyl cellulose (CMHEC) and Hydroxypropyl guar (HPG), however, the derivatized cellulose-based polymers run contrary to the green chemistry phenomenon. Therefore, there is a need to develop a polymer that supports the principles of green chemistry and this paper has been able to address this gap. Thus, a series of experiments were conducted on imported polymer (Hydroxyethyl cellulose) and local polymers (cassava starch) as viscosifying agents in the cement slurry. A concentration of 0.1% by weight of cement slurry densities of 14ppg and 15.8ppg were used for different polymers to compare the shear stress behavioral tendencies at different temperatures range of 80°F (29°C), 120°F (49°C), 150°F (66°C), and 190°F respectively. For the imported and local polymers, it was observed that as the temperature increases there was a corresponding increase in the shear stress, however, maximum shear stress was obtained at the lowest shear rate of 5.11sec⁻¹ and minimum shear stress was obtained at the highest shear rate of 510.69sec⁻¹ Further investigation was done using statistical analysis (ANOVA) and results showed that the level of significant difference is 0.05, meaning that there is no significant difference between imported (Hydroxyethyl cellulose) and local polymers (cassava starch) meaning local polymers are a better alternative and can be substituted to the cellulose-based polymer.

Keywords: Cement slurry, Polymers, hydroxyethyl Cellulose (Hec), amylose/amylopectin, rheology

1. Introduction  
The integrity and longevity of oil or gas wells are dependent upon the cementing activities, therefore, cementing operation is a critical feature of wellbore completions. Life and properties have been jeopardized due to improper design and cementing of oil and gas wells. Oil spills such as the recent Gulf of Mexico Deepwater horizon oil spill are some of the causes of oilloss from the global reserve. Besides economic losses, material that is in line with the principles of green chemistry is advocated so as to minimize the use of derivatized additives in cementing activities. The benefits are not only health and environment-related, but also economical, as the costs of storage, regulation and protecting workers and the public from exposure to hazardous chemicals are reduced. Folić et al. (2010) disclosed that attention must be paid on the interaction of cement concrete with its environment because its chemical orientations have the tendency to influence the likely mechanisms of deterioration. Furthermore, the ability of cement concrete to resist chemical attack, abrasion, weathering action, and other deterioration effects is critical during the service life of the structure. However, additives used in cement slurry play an essential role in achieving good quality cementation which will enhance durability in cementing operations. Again, deterioration mechanisms in cement slurry are influenced by interaction with the environment. The system design of cement slurry and the engineering structures that involve materials selection should be carried out in a manner that is environmentally friendly because this will contribute to environmental sustainability which is in line with the principle of green chemistry. It is essential to ensure that the natural environment is not being altered by the chemicals also known as additives used in oil and/or gas drilling and completion activities. Among the twelve principles published by

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Anastas P. T and Warner J. C (1998) to guide the practice green chemistry, it is advocated that unnecessary generation of derivatives such as the use of protecting groups should be minimized or avoided if possible. Thus, the beauty of this product, is such that it addresses the utmost importance for chemistry and chemical technology in terms of safety, usefulness as well as to enjoy public trust. Furthermore, this product has respect for the environment and also it is economically valuable and readily available. The product drives a key initiative in the ongoing efforts to achieve global sustainable development in the country.

Cementing mid to high-temperature wells poses a challenge for these types of polymer hence, polysaccharides and their derivatives are unstable at high temperature. According to Reddy et al. (2012), polysaccharides-based cement slurries exhibit a steady manner of losing viscosity and strength with increasing temperature which creates the problems of fluid loss through the slurry as well as a reduction in compressive strength, gas migration and ultimately causes the well to be abandoned. Due to the rheological effect, a high concentration of polymer is being used to maintain the viscosity of the cement slurry at an elevated temperature. However, increasing the concentration of polymers in cement slurry causes viscosification of the slurry at the surface condition, which then requires high pumping pressure. Additional pumping pressure may cause serious problems of formation damage and loss of circulation. These types of polymer-based cement slurry create problems due to the high concentration of polymer. Reddy (2011) stated that hydroxyethyl cellulose (HEC) polysaccharides polymers that are currently used in cementing operations have been synthesized and modified with organic carbonate to retain the viscosity of the polymer solution at ambient temperature and increase the viscosity at high temperature. The usage of chemicals in cement slurry affects the properties of other additives and increases the cost of the cementing operation. On other hands, unnecessary derivatization (use of blocking groups, protection/de-protection, and temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.

According to Anastas P. T and Warner J. C (1998), several laboratory chemicals are controversial from the perspective of green chemistry and most of the additives used as viscosity enhancer in cementing operations are derivatized polymers and that is what gave birth into researching on an alternative additive that complies with the principles of green chemistry. As mentioned, Reddy (2011) disclosed that hydroxyethyl cellulose (HEC) polysaccharides polymers have been synthesized and modified with organic carbonate to retain the viscosity tendency. The presence of carbonate in hydroxyethyl cellulose (HEC) makes it detrimental to the agricultural environment especially when it is in larger quantity meaning that the region becomes arid, thereby, characterized by a severe lack of available water, to the extent of hindering or preventing the growth and development of plant and animal life. Environments subject to arid climates tend to lack vegetation because of the excess alkal and alkaline metals. Such an environment is also referred to as xeric or desertic, an example of places is mostly found in Africa and parts of South America, Central America, and Australia. These alkaline metals are naturally formed and its order of abundance are as follows: sodium, potassium, lithium, rubidium, caesium, and finally francium, which is very rare due to its extremely high radioactivity; francium occurs only in the minutest traces in nature as an intermediate step in some obscure side branches of the natural decay chains. Thermal instability of hydroxyethyl cellulose (HEC) could be contributed due to the presence of carbonate thus, carbonate decomposes upon heating forming carbon dioxide and oxide.

Therefore, it is necessary to use a type of polymer that can retain the viscosity of the cement slurry at ambient temperature and have thermal thickening properties with increasing temperature. The paper address polymer (cassava starch) that acts as a self-active viscosifier at gelation temperature and is sustainable at a higher temperature. Amylose/amylopectin-based polymer (cassava starch), as a self-active viscosifier, has no need of any other chemical to increase the viscosity at temperatures ranging from 80°F (29°C) to 190°F (88°C) which is the advantage of this polymer over other cellulose-type polymers. Again, the novelty of this product is that it promotes and comply with the principle of green chemistry. Although, amylose/amylopectin in-based polymer may require some treatment to enable its use in temperature above 190°F (88°C) regimes to ensure stability.

2. Research Methodology

2.1. Research study Area and Methods

Raw samples were collected from the South-East geopolitical zone of Nigeria. Preparation of the raw samples was done in accordance with the Food and Agricultural Organization (FAO) procedures. Thereafter, laboratory analyses were conducted to ascertain American Petroleum Institute (API) standard to ensure it meets specifications prior to usage.

2.2. Preparation of Cement Slurry

Dry samples of three cultivars were used for the experiments. Two different cement slurry densities such as 14 and 15.8ppg were prepared with a concentration of polymers 0.10%BWOC as shown in Tables 1 and 2. Samples were weighed and then blended uniformly before added to the mixing fluids. Standard CTC constant speed mixer (Model-7000) of 1.2L capacity was used to an obtained homogenous mixture. The mixer motor is turned on and maintained at (4000±200 rpm) according to API RP10-2B procedure (API Edition, 2009). Water and fluid additives were then stirred above rotational speed to thoroughly disperse them prior to cement addition. The cement and solid additives blend were added at a uniform rate, in not more than 15 seconds. After the addition of all dry materials to the mix water, the mixing speed is increased to 12000±500 rpm for 35 seconds. Dry materials (cement and solid additives) and water temperature should be kept at 23±1.10°C prior to the mixing. The difference in the laboratory quantities of the additives is due to the difference in the specific gravity of the imported and local polymers as shown in Tables 1 and 2.
Additives | Laboratory Quantities for 600ml API @ 0.10 % Bwoc
--- | ---
 | Volume (ml) | Weight (g)
Imported Polymer (HEC) | 190.24 | 190.22
Local Polymer (PG) | 597.35 | 597.28
Imported Polymer (HEC) | 4.24 | 4.24
Local Polymer (PG) | 3.77 | 3.78
Cement (class G) | 405.09 | 405.16
Polymer | 0.43 | 0.38
Antifoam (FP-30L) | 0.60 | 0.60
Freshwater | 405.09 | 404.74
Total | 600.00 | 1006.81

Table 1: Cement Slurry Design for 14ppg

Additives | Laboratory Quantities for 600ml API @ 0.10 % Bwoc
--- | ---
 | Volume (ml) | Weight (g)
Imported Polymer (HEC) | 250.77 | 787.42
Local Polymer (PG) | 787.33
Polymer | 0.52 | 0.50
Antifoam (FP-30L) | 5.59 | 3.77
Freshwater | 343.07 | 4.98
Total | 600.00 | 1136.26

Table 2: Cement Slurry Design for 15.8ppg

2.3. Rheology of Slurry

After the sample preparation, the cement slurry was homogenized at a rotational speed of 150 rpm for 20 minutes in an atmospheric consistometer. To examine the rheological properties of the cement slurries of laboratory analysis of each cement slurry was determined at various temperatures ranging from 80 to 190°F (29 – 88°C). The apparatus used for the test is a concentric cylinder device (Couette Flow) commonly used in the oilfield (Fann VG 35A)(API RP 13B- 2016). After the homogenization, the slurry is placed at the test vessel. The torque response for each rotational speed provided by the equipment (300, 200, 100, 6 and 3 rpm) (511, 340,171 and 10 s⁻¹, respectively) is recorded. The equipment also provides reading at 600, but not considered in this study since there is controversy concerning the guarantee of laminar rheometric flow at the higher speed for several slurries. The rheological values were obtained from viscometer and various calculations were obtained as shown below. Thus, the reference for measuring viscosity and performing calculations in accordance with American Petroleum Institute specifications (API RP 13B-1/ISO 10414-1 (2016). However, features and specifications for Model 35 Fann direct-indicating viscometer used are equipped with the standard R1 rotor sleeve, B1 bob, F1 torsion spring, and a stainless-steel sample cup. So, the constant values used for the calculations are according to the stipulated standard for R1-B1-F1. The readings obtained from viscometer are converted to oilfield units to obtained values for shear stress and shear rate by using the equations (1) and (2).

2.4. Calculation of Shear Stress and Shear Rate:

For (R1-B1-F1):

Shear stress (lb/100ft²) = 1.065 x 1° Fann
(1)
Shear rate (sec⁻¹) = 1.7023 x rpm, N
(2)

N = Rate of revolution of the outer cylinder, rpm
θ = Fann viscosity reading

2.5. Calculation of Plastic Viscosity (PV) and Yield Point (YP)

Plastic viscosity (PV) and yield point (YP) of the cement slurries were calculated using equations (3) and (4). For simplification purposes, Bingham fluid model as shown in Figure2 can be used to determine PV which represents the slope of a straight line between the two dial readings and YP which represents the theoretical point at which the straight line, when projected, will intercept the vertical axis.

$PV (cP) = \left( \theta_{300} - \theta_{100} \right) \times 1.5$ (3)

$YP (lb/100ft^2) = \theta_{300} - PV$ (4)

Where θ is the dial reading?
Gel strength at 10 seconds and gel strength at 10 minutes were obtained from the viscometer immediately after the desired time, at the first deflection. This is in accordance with the American Petroleum Institute Specification procedure (API RP 13B-1/ISO 10414-1, 2016).

3. Results and Discussions

The aim of the study was to compare the viscosifying tendencies of three samples of amylose/amylopectin-based polymers (cassava starches) namely 96/1632 (PG1); 98/0505 (PG2) and 92/0057 (PG3) with the currently used viscosity enhancer cellulose-based polymer (hydroxyethyl cellulose-HEC). It was observed that at cement slurry densities of 14ppg and 15.8ppg for different temperature test of 80°F (29°C), 120°F (49°C), 150°F (66°C), and 190°F respectively, at the lowest shear rate of 5.11sec⁻¹, HEC showed maximum shear stress of 33.046lb/100ft² and a minimum shear stress of 9.594lb/100ft²; 96/1632 (PG1) showed maximum shear stress of 28.782lb/100ft² and minimum shear stress 9.594lb/100ft²; 98/0505 (PG2) showed maximum shear stress of 30.914lb/100ft² and minimum shear stress of 6.396lb/100ft² and 92/0057 (PG3) showed maximum shear stress of 22.386lb/100ft² and minimum shear stress of 5.330lb/100ft². Whereas at highest shear rate of 510.69sec⁻¹, HEC showed maximum shear stress of 82.082lb/100ft² and minimum shear stress of 26.653lb/100ft²; 96/1632 (PG1) showed maximum shear stress of 89.544lb/100ft² and minimum shear stress of 26.654lb/100ft²; 98/0505 (PG2) showed maximum shear stress of 83.148lb/100ft² and minimum shear stress of 23.452lb/100ft² and 92/0057 (PG3) showed maximum shear stress of 73.554lb/100ft² and minimum shear stress of 19.188lb/100ft² as indicated in Figures 3, 4, 5, 6, 7, 8, 9 and 10. It means that there was an incremental trend of shear stress vs shear rate at different temperatures for the three samples of local polymers (cassava starches) and HEC thus, this is in line with the findings of Brandlet et al., 2011; Reddy et al, 2012 which disclosed that HEC exhibited excellent shear stress/shear rate tendency within the temperature range of 30 to 90°C. Furthermore, graphs show a linear relationship between the shear stress and the shear rate meaning the cement slurries do not flow until the shear stress exceeded the critical values know as yield point and at point shear stress and shear rate become proportional with increasing temperatures. It then implies that the flow of the slurries follows the pattern of Bingham plastic behaviour. The cement slurries were viscous at high shear rate due to the fact that the chemical bond structure of amylose/amylopectin-based polymer was not disturbed evenly and this now led to molecular coagulation with respect to increase in temperature. Again, the increase in the viscosity of amylose/amylopectin in-based polymer cement slurries is due to the hydrophobic interaction between the molecules of the hydroxyl group. Furthermore, as the side chains of the monosaccharides form as many hydrogen bonds as possible with themselves, water cannot intrude the molecules, making them hydrophobic. This property allows the molecules to stay together and not dissolve into the cytosol. This lowers the sugar concentration in a cell, and more sugar can then be taken in. Not only do polysaccharides store the energy, but they allow for changes in the concentration gradient, which can influence the cellular uptake of nutrients and water. With increasing temperature, the amylose/amylopectin-based polymer loses the water of hydration, which becomes the cause of the increase of viscosity. When cement slurries are further heated and shear is applied the swollen granules integrate into flocculated fragments and finally form a colloidal solution that has a higher viscosity. During this temperature-and time-dependent process, first the starch molecules in the amorphous region begin to imbibe water and the granules begin to swell if more and more heat is transferred; this also happens in the crystalline regions and the birefringence is lost. This loss of birefringence occurs at a specific temperature interval which is characteristic of the starch type. With the swelling of the granules, the viscosity of the system increases until the maximum granule size is reached, as the viscosity is mainly caused by the interaction of the swollen granules. However, the functional properties of starch become apparent after the so-called gelatinization of the starch granules. These properties are responsible in the viscosity/rheology, water retention, binding power/dry strength, emulsion/suspension stabilization as well as film formation.

Figure 2: Shear Stress-Shear Rate Relationship for Bingham Plastic Fluid
Figure 3: Variation of Shear Stress Vs Shear Rate of 0.1% BWOC of HEC of 14ppg Density at Different Temperatures

Figure 4: Variation of Shear Stress Vs Shear Rate of 0.1% BWOC of 96/1632 (PG1) of 14ppg Density at Different Temperatures

Figure 5: Variation of Shear Stress Vs Shear Rate of 0.1% Bwoc of 98/0505 (PG2)Of 14ppg Density at Different Temperatures
Figure 6: Variation of Shear Stress Vs Shear Rate of 0.1% BWOC of 92/0057 (PG3) of 14ppg Density at Different Temperatures

Figure 7: Variation of Shear Stress Vs Shear Rate of 0.1% BWOC of HEC of 15.8ppg Density at Different Temperatures

Figure 8: Variation of Shear Stress Vs Shear Rate of 0.1% BWOC of 96/1632 (PG1) of 15.8ppg Density at Different Temperatures
By concentration of 0.10% bwoc of various polymer samples, it was observed that plastic viscosities increased with increasing temperatures of 80°F (29°C) to 190°F (88°C) as shown in Figures 11 and 12 at cement slurry densities of 14ppg and 15.8ppg respectively. At a density of 14ppg of 0.10%bwoc of cassava starch laboratory analyses carried indicated values of plastic viscosities of 96/1632 (PG1) were within ranges of 5 to 33 cP; 98/0505 (PG2) were within ranges of 6 to 24 cP and of 92/0057 (PG3) were within ranges of 13 to 32 cP at temperature of 80°F (29°C) to 190°F (88°C). whereas at the same concentration of polymers at 15.8ppg the values of plastic viscosities of 96/1632 (PG1) were within ranges of 20 to 56 cP; 98/0505 (PG2) were within ranges of 24 to 69 cP and of 92/0057 (PG3) were within ranges of 22 to 42 cP and HEC within ranges of 25 to 51 cP, meaning that cassava starch compared favourably with hydroxyethyl cellulose polymer. Field practice shows that best cement slurry plastic viscosity should be less than 100 cP, it then implies cassava starch could be recommended as viscosifier in cementing operations. Moreso, a high value of plastic viscosity will create a problem in pumpability of the cement slurry.

Figure 11: Plastic Viscosity as a Function of Different Temperature (°F) of the 14ppg Cement Slurry for Different Polymers
Furthermore, yield point and gel strength of cement slurries were evaluated as shown in Figures 13, 14, 15, 16, 17 and 18 respectively. It was also observed that there was a corresponding increase in the yield point and gel strength with increase in temperatures, meaning that temperatures have a drastic effect on the properties. At a density of 14ppg of 0.10%bwoc of cassava starch laboratory analyses carried indicated values of yield point of 96/1632 (PG1) were within ranges of 12 to 38 lb/100ft²; 98/0505 (PG2) were within ranges of 10 to 41 lb/100ft² and of 92/0057 (PG3) were within ranges of 11 to 30 lb/100ft² and HEC was within ranges of 21 to 39 lb/100ft² at temperature of 80°F (29°C) to 190°F (88°C). Whereas at same concentration of polymers at 15.8ppg the values of yield point of 96/1632 (PG1) were within ranges of 31 to 105 lb/100ft²; 98/0505 (PG2) were within ranges of 31 to 97 lb/100ft² and of 92/0057 (PG3) were within ranges of 33 to 81 lb/100ft² and HEC within ranges of 29 to 69 lb/100ft², meaning that cassava starch compared favourably with hydroxyethyl cellulose polymer. Again, cement slurry densities of 14ppg and 15.8ppg of cassava starch at temperatures of 120°F (49°C) to 190°F (88°C) yield point were above 15lb/100ft², this is an indication of the fact that the slurries are stable which is an integral part that must be considered in cement slurry design so as to prevent slurry settling characteristics and it agrees with observation of Crook, R. J et al (1987). Although, this could be a problem at the time of pumping at the surface condition. The gel strength and viscosity of the slurries increase with increased temperature, which was due to the water absorption on its hydroxyl group. However, the absorption of water and increase of viscosity keep the slurry stable at high temperature.
Figure 14: Yield Point as a Function of Different Temperature (°F) of the 15.8ppg Cement Slurry for Different Polymers

Figure 15: Gel Strength @10seconds as a Function of Different Temperature (°F) of the 14ppg Cement Slurry for Different Polymers

Figure 16: Gel Strength @10seconds as a Function of Different Temperature (°F) of the 15.8ppg Cement Slurry for Different Polymers
Figure 17: Gel Strength @10minutes as a Function of Different Temperature (°F) of the 14ppg Cement Slurry for Different Polymers

Figure 18: Gel Strength @10minutes as a Function Of Different Temperature (°F) of the 15.8ppg Cement Slurry for Different Polymers

| Polymer | Plastic Viscosity Design for 14ppg (cP) | Yield Point (lb/100ft²) | Plastic Viscosity Design for 15.8ppg (cP) | Yield Point (lb/100ft²) |
|---------|----------------------------------------|-------------------------|------------------------------------------|-------------------------|
| HEC     | 20.62±9.44                             | 32.13±14.24             | 59.63±10.77                              | 45.13±13.36             |
| PG1     | 22.88±12.39                            | 34.38±13.85             | 79.88±15.51                              | 53.38±24.93             |
| PG2     | 31.50±14.23                            | 22.00±10.16             | 65.25±25.97                              | 60.00±13.23             |
| PG3     | 22.50±13.13                            | 17.00±9.51              | 65.25±21.02                              | 51.75±17.08             |

Table 4: Analysis of Variance for Plastic Viscosity and Yield Point
Level of Significant = 0.05

Figure 19: Mean Plastic Viscosity Chart for 10secs and 10mins
Figure 20: Mean Yield Point Chart for 10secs and 10mins

| Polymer | Cement Slurry Design for 14ppg | Cement Slurry Design for 15.8ppg |
|---------|--------------------------------|----------------------------------|
|         | Gel Strength @ 10 Sec          | Gel Strength @ 10 minutes        | Gel Strength @ 10 Sec          | Gel Strength @ 10 minutes        |
| HEC     | 21.00±9.59                     | 31.75±14.01                     | 44.75±13.45                   | 60.00±10.67                     |
| PG1     | 23.25±12.50                    | 34.00±13.88                     | 52.00±26.36                   | 81.25±13.77                     |
| PG2     | 22.25±10.53                    | 31.25±13.72                     | 59.75±13.05                   | 65.50±26.10                     |
| PG3     | 17.75±9.98                     | 22.75±12.87                     | 51.50±16.82                   | 62.50±21.27                     |

Table 4: Analysis of Variance for Gel Strength

Figure 21: Mean Gel Strength Chart for 10secs and 10mins at 14ppg

Figure 22: Mean Gel Strength Chart for 10secs and 10mins at 15.8ppg
The result for Table 4 and 5 showed that, for cement slurry design for 14 ppg the average plasticity viscosity of HEC was 20.62 (SD = 9.44), while the average of PG1, PG2 and PG3 were 22.88 (SD = 12.39), 31.50 (SD = 14.23) and 22.50 (SD = 13.13) respectively. There was no significant difference between the plastic viscosity of the four different polymers used as viscosifier. This result indicates that the local polymers (cassava starch) designated as PG1, PG2, and PG3 can be used as a replacement for HEC and accurate plastic viscosity would still be obtained. The average yield point of HEC was 32.75 (SD = 14.10), while the average of PG1, PG2, and PG3 were 34.38 (SD = 13.85), 22.25 (SD = 10.57) and 17.75 (SD = 9.98) respectively. The result from the ANOVA for yield point also showed that there was no significant difference among the polymers. The similar result was noticed for cement slurry design for 15.8 ppg, with no significant difference in both the plastic viscosity and yield point.

The average gel strength for 10 sec for cement slurry design for 14 ppg was 21.00 (SD = 9.59) for HEC polymer, while the gel strength at 10 seconds for local polymers (PG1, PG2, and PG3) were 23.25 (SD = 12.50), 31.25 (SD = 13.72) and 22.75 (SD = 12.87) respectively. There was no significant difference for gel strength at 10 seconds between the polymers. For gel strength at 10 minutes, showed that HEC polymer had a gel strength of 31.75 (SD = 14.0), while local polymers (PG1, PG2, and PG3) had gel strength of 34.00 (SD = 13.88), 22.25 (SD = 10.75) and 17.75 (SD = 9.98) respectively. The result was also consistent for cement slurry design for 15.8 ppg, as there was no significant difference for both the gel strength at 10 seconds and that at 10 minutes.

Furthermore, Figure 19, shows the mean plate viscosity for the different viscosifier at 14ppg and it was observed that local polymer (PG2) had the highest mean plastic viscosity. This shows that PG2 was slightly higher than the imported polymer (HEC). For the mean plastic viscosity at 15.8ppg, the local polymer (PG1) was higher than the imported polymer (HEC). From Figure 20, the local polymer (PG1) showed a higher yield point as compared to the imported viscosifier (HEC) at 14ppg while at 15.8ppg the local polymer (PG2) showed a higher yield point as compared to the imported viscosifier (HEC). From Figure 21, the local polymer (PG1) gave a higher mean gel strength at 10 seconds than the imported polymer (HEC) whereas at 15.8ppg the local polymer (PG1) gave a higher mean gel strength at 10 second.

4. Conclusion

- Test results revealed that the local polymers cement slurries (cassava starch) exhibited excellent shear stress/shear rate profiles, therefore, it shows that it could be used as a viscosifying agent.
- The local based polymer cement slurries also exhibited thermal stability between the test temperature of 80°F (29°C) to 190°F (88°C).
- At 0.1% bwoc concentrations of amylose/amylopectin-based polymer cement slurries (cement starch), the cement slurries have improved rheology in terms of plastic viscosity, yield point, and gel strength.
- The high gel strength of 15.8ppg cement slurry density of amylose/amylopectin-based polymers (cassava starch) requires high pumping pressure at the surface condition. However, friction reduction additives should be used in 15.8ppg based cement slurries to reduce the gel strength.
- At high temperature, local based polymer cement slurries polymer shows thixotropic behaviour that should be beneficial for controlling gas migration through the cement slurry.
- The local polymers can be used as a replacement for imported polymer (HEC) since result with the local polymer compared favourably.

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