Evaluation of the suitability of Carboxylmethyl Cellulose (CMC) from Rice Husks/Saw Dust as Replacement for Conventional Hydroxy Ethyl Cellulose (HEC) as additive for cement slurry design

Abstract

This study will evaluate the suitability and effectiveness of using Cellulose derived from Rice husk and Saw dust as cement slurry additive to replace the conventional cellulose in order to minimize cost and optimize drilling.Rice husks and Saw dusts were processed and Carboxylmethyl Cellulose (CMC) extracted with Sodium Hydroxide,Ethanol and Sodium Monochloroacetate. Three cement slurry samples from the produced CMC (Rice husks and Saw dust) and the conventional HEC were formulated. Different mass percent concentration of 0.2, 0.4, 0.6,0.8 and 1 of the CMC from Rice husks ,Saw dust and Conventional HEC were added and subjected to different temperature conditions of 200^{o}F,300^{o}F, 400^{o}F,500^{o}F ,600^{o}F.Rheological Properties of the formulated cement slurry such as Yield point and Plastic viscosity were tested at those temperature conditions. Results show that the yield point for all the temperature conditions and the additive concentration for the CMC from Rice husks and Saw dust have the same trend with the conventional HEC. Also, the plastic viscosity of the CMC from the Rice husks and Saw dust were in agreement and same trend with the conventional HEC.The results reveals that cellulose prepared from Rice husks and Saw dust gave almost the same rheological properties with that of the convention HEC and can be used in place of conventional HEC to reduce cost and also achieve the same results.

Keywords: Cement Slurry, Hydroxy Ethyl Cellulose, Carboxylmethyl Cellulose, Rice Husks, Saw Dust

1.1 Introduction

Cementing is an integral part of well completion operations and its design requires proper and adequate selection of the cement type, additives, slurry properties and cost analysis. Cementing is done essentially in an oil, gas or water well to provide zonal isolation and for excluding each zone from one another in several producing zones by creating a seal in the annular space between the casings and the wellbore to ensure wellbore integrity (King & King, 2013). Wellbore operations such as drilling, completion, stimulation jobs, pressure integrity test (PIT) and production can compromise the annular cement and cement interfaces integrity (Heathman & Beck, 2006). Therefore, understanding the failure mechanisms under different operating conditions can be integrally linked to a more accurate assessment of wellbore integrity (Arjomand *et al*.2018). The failure of cement sheath in the wellbore has been identified to be dependent on the wellbore architecture and the mechanical properties of the cement slurry (Bosma *et al*., 1999; Shahri *et al.*,2005; Griffith *et al*., 2004; Gray *et al*,.2009; Li *et al.* 2010 and Bios *et al.*, 2010). As producing well ages with time and the result of the subjected down hole fluids, pressures and temperature; the mechanical properties of the down hole equipment are eventually depreciated (Ramos and Camus, 2017). This degrading life of the well equipment often leads to increase in the number of well integrity issues affecting the *Sustained Casing Pressure (SCP)*. (Lavrov and Torsæter, 2016) stated that in about 15,500 wells assessed in the Gulf of Mexico that wells of 15years old have a 50% probability of experiencing integrity issues caused by well aging with actual overall percent of wells suffering from this up to 35%. Similar figures were also generated for wells in the North Sea which in some cases required remedial cementing jobs. This remedial cementing rather being a solution can often become a problem itself. This is as a result of complexities associated with damage to the producing zones and well stimulation issues. Hence proper cement formulation and placement are essential in ensuring well integrity throughout the producing life of the well. One sure way of achieving this is via the use of appropriate cement additives. In the oil and gas industry, Portland cement (class G) has been specifically used for oil well cementing. This is because of its ability to withstand very low temperatures in permafrost zones to high temperatures 662^{o}F in geothermal wells and also sustain a pressure of about 30,000psi typical of high pressure wells (Broni-Bediako *et al.,* 2016). Achieving this pressure and temperature conditions has been shown by (Magarini *et al*,.,1999) manual to be possible via the use of some additives with the Portland cement. Cement slurry additives are materials added to modify or rather enhance the particular cement slurry property/(ies) of interest (Anon, 1997). Cement additives selected for cementing operations forms a major part of sound well design, construction and well integrity (Bett, 2010), Additives serves to enhance the properties of oil well slurries and achieve successful placement between the casing and the geological formation, rapid compressive strength development and adequate zonal isolation during the lifetime of the well (Magarini et al, 1999). Additives are added during cement formulations to assist in dispersing cement particles, modify the setting time under temperature and pressure conditions in the well, control filtration losses of the liquid from the cement slurry during and after placement, compensate for shrinkage of the cement as it sets and hardens, improve interfacial bonding between cement and casing, control influx and migration of formation fluids into the cement column during setting (Cowan & Eoff, 1993). Cement rheological properties, compressive strength, thickening time, wait on cement and additives can affect the quality of the cement and the bond integrity. Wrong cement formulation and composition of the slurry can result to inadequate cement to formation and cement to casing bonding. Cement slurry contamination by formation fluid or drilling mud can alter the properties of the slurry and makes it shrink during hydration process and thus results to poor cement bond quality. Design of slurry should consider the formation temperature, properties, stress changes in order to avoid shrinking and borehole collapse. In recent times where drilling has proceeds to high pressure and high temperature(HPHT) formation with much challenge of controlling the slurry properties, it is vital to monitor the design of slurry to combat the challenge. HPHT wells whose pressure is above 15,000psi and temperature above 300^{o}F increases sensitivity of the cement slurry to high temperature which reduces the thickening time and makes cement set faster than in average temperature well. Since high temperature affects rheological properties and fluid loss ability with compressive strength of slurry, it is important to design slurry that will withstand formation stress and enhanced proper casing to formation bonding. It is imperative to note that cost of additives must be minimized while retaining bonding ability. Recently, Nano particles and Carboxylmethyl Cellulose (CMC) has been extracted as mud agent for fluid loss control from several local materials (saw dust, rice husks, coconut shell, coconut cobs, cassava peels, periwinkle shell ash) and found to perform optimally and can replace the conventional Hydroxyethyl Cellulose(HEC) or Polyaniomic Cellulose (PAC).

Cement slurry is formed by mixing cement, water and various additives. The major reason for cementing is prevention of water inflow into productive zones of the reservoir and also to regulate the size of the gas index and water-oil quotient, and for various technological operations of casing columns (Zheng et al 2014).During drilling operations, cement slurry is pumped into the annular space between the casing pipes and the borehole and after circulation breaking, thickening and bonding occurs before it hardens and seal the annular space. Cement slurries with various additives are also used to remove the drilling mud that escape or to stop the lost of mud in to thief zones or open formation (Jianjun & Xianbin, 2012).

The design of cement slurry for a geothermal well considers a careful choice of cements, accelerators, retarders, viscosifiers, lost circulation agents, fluid loss additives, dispersants, extenders, friction reducers, defoamers and mix water and correct placement of slurry in the annulus. The design of a cement slurry system for casing stability during drilling process can be effective if the available cementing system are known and understood (Gazolu, 2006). Therefore, this work will compare CMC extracted from saw dust and Rice husks with Conventional HEC as additives for cement slurry design for high temperature zone at an optimum cost.

2. Material and Method

2.1 Materials used

i. High Pressure/High Temperature (HPHT) Consistometer
ii. Static Fluid Loss Cell
iii. Cement Mixing Blender
iv. Viscometer
v. Hydroxyethyl cellulose (HEC)
vi. Defoamer
vii. Freshwater
viii. Class G Cement (Portland Cement)
ix. 250 ml Cylinder
x. Foil paper
xi. Stop watch
xii. Weighing balance

xiii. HTHP Filter press

xiv. Filter paper and meter rule

xv. Carver Compressive machine

xvi. Carboxy methyl Cellulose (Extracted from Rice Husk and Saw dust)

xvii. Speed mixer.

2.2 Preparation of Cement Slurry Samples and Rheology Test

Powdered class G cement was weighed and blended before uniformly adding to the mixing fluids with the mixer motor turned on and maintained at (4000±200 rpm). Water and the additives were properly stirred at the specified rotational speed for uniform dispersion in the mixtures. The cement and solid additives blend were added at a uniform rate in not more than 15 seconds. The mixing speed was increased to 12000±500 rpm for 35 seconds after addition of all the additives. Dry materials (cement and solid additives) and water were continuously blended at a temperature of 23±1.1^{0}C. The cement slurry was homogenized at a rotational speed of 150 rpm for 20 minutes in an HPHT consistometer. The temperature of the slurry was kept constant. The rheology was determined with a Fann VG- 35A. After the homogenization, the slurry was placed at the test vessel. The torque response for each rotational speed provided by the equipment (300, 200, 100 and 6 rpm with corresponding time 511, 340, 171 and 10s-1, respectively) was recorded. Readings at 600 and 3 rpm was not considered due to the controversy concerning the guarantee of a laminar rheometric flow at the higher speed for most slurry. Notably, there is frequently poor repeatability of readings at the lower speed. The cement additive properties and values are shown in Table 1 and 2

Table 1: Cement Additives Properties

S/N	Additives	S.G	Relative Density (g/cm^3)	Concentration	Volume (L)	Weight (Kg)
1	**Freshwater**	1.00	1.00	-	X	X
2	**HEC**	1.4	1.4	0.2% bwoc	0.080	0.112
3	**Defoamer**	0.9	0.90	0.089L/MT	0.089	0.0801
4	**Class G Cement**	3.14	3.14	100% bwoc	31.70	100
	Total	-	-	-	X+31.87	X+100.19

Table 2: Values of Cement Additives

S/N	ADDITIVES	VOLUME (L)	WEIGHT (Kg)
1	**Freshwater**	X = 44.89	44.89

2	**HEC**	0.080	0.112
3	**Defoamer**	0.089	0.0801
4	**Class G Cement**	31.70	100
	Total	76.759	145.0821

2.3 Procedure and Preparation of CMC

2.3.1 Preparation from Saw Dust (SD)

- Saw dust was sundried for twenty-four (24) hours, grinded to powdered form and sieved with a 100μm size screen.
- 30 grams of the powder was measured and reacted with 10 mol of aqueous Sodium Hydroxide (NaOH).
- The solution was stirred for 30 minutes at room temperature, filtered and washed with 96% ethanol and distilled water to remove the alkali.
- The residue (cellulose) was heated at 60°C and 24 grams of acid Sodium Monochloroacetate reacted with 20 grams of heated residue (sodium cellulose) and dissolved in 200ml of deionized water.
- The solution was filtered and washed with 70% ethanol for three (3) times with deionize water and residue (CMC) heated to 60°C until dried.

2.3.2 Preparation from Rice Husk

- Rice husk was sundried for twenty-four (24) hours and grinded in to powder and sieved with a 100μm size screen.
- 30 grams of the powder was measured and reacted with 10 mol of aqueous Sodium Hydroxide (NaOH).
- The solution was stirred for 30 minutes at room temperature, filtered and washed with 30 ml of 96% ethanol and 30 ml distilled water to remove the alkali.
- The residue (cellulose) was heated at 60°C and 24 grams of acid Sodium Monochloroacetate reacted with 20grams of heated residue (sodium cellulose) and dissolved in 200ml of deionize water.
- The solution was filtered and washed with 30 ml of 70% ethanol for three(3) times with deionize water and residue (CMC) heated to 60°C until dried.

2.3.4 Purification of CMC

30 grams of the synthesize CMC produced was dissolved in 100ml of distilled water, heated at 80°C and stirred for several minutes. The CMC was centrifuged for one minute at 4000rpm.

3. Results

3.1 Yield Point of the Cement Slurry

Figure 1 to 5 shows the effect of HEC/CMC concentration on the slurry yield value for different temperature conditions. At 200°F, there was a consistent increase in yield point with additive increment for each additive as presented in Figure 1. The result shows that at a low temperature, the slurry has not lost its strength and still retains thermal stability.. Above 300°F, more complex trends of yield point variation were observed for each test point temperature which relatively tends to linearize with increasing temperature. This is a result of increasing complexity of chemical reaction processes which are associated with slurry setting.

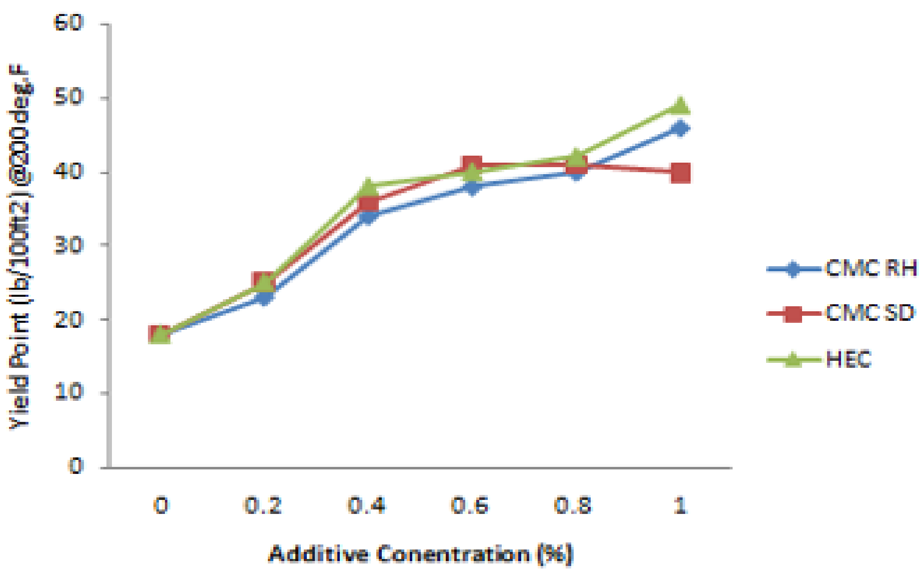

Figure 1: Effect of Additive Concentration on Slurry Yield Point at 200 ^{0}F

For 300°F,the slurry yield point initially drop for 0.2% concentration of the additive before increasing after attaining stability up to the last concentration as shown in Figure 2.

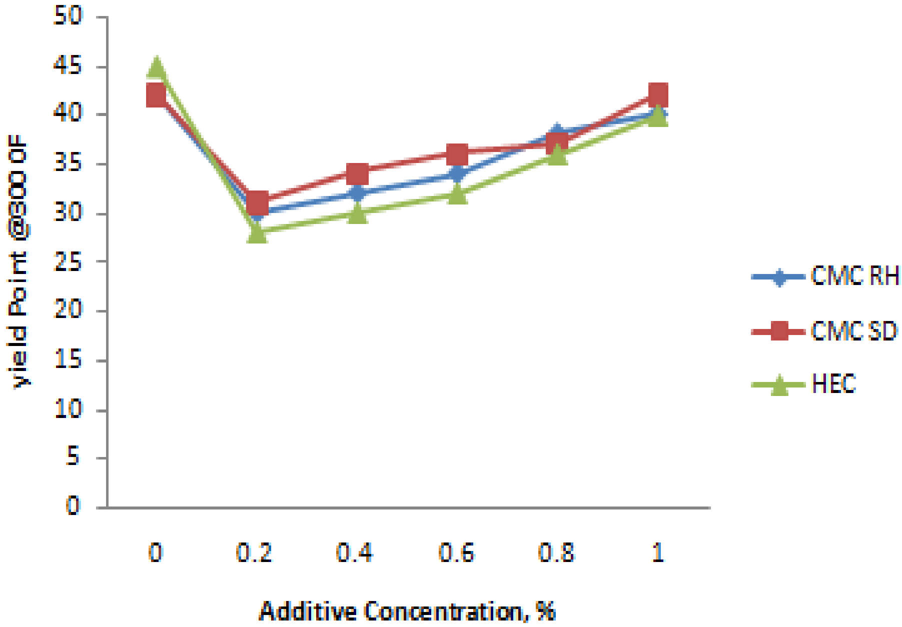

Figure 2: Effect of Additive Concentration on Slurry Yield Point at 300 ^{0}F

Figure 3 shows the effect of additive concentration on the slurry yield point at 400^{o}F.Adecline was observe from 0 to 0.4% additive concentration and increased steadily after attaining stability from 0.6% to 1% concentration.

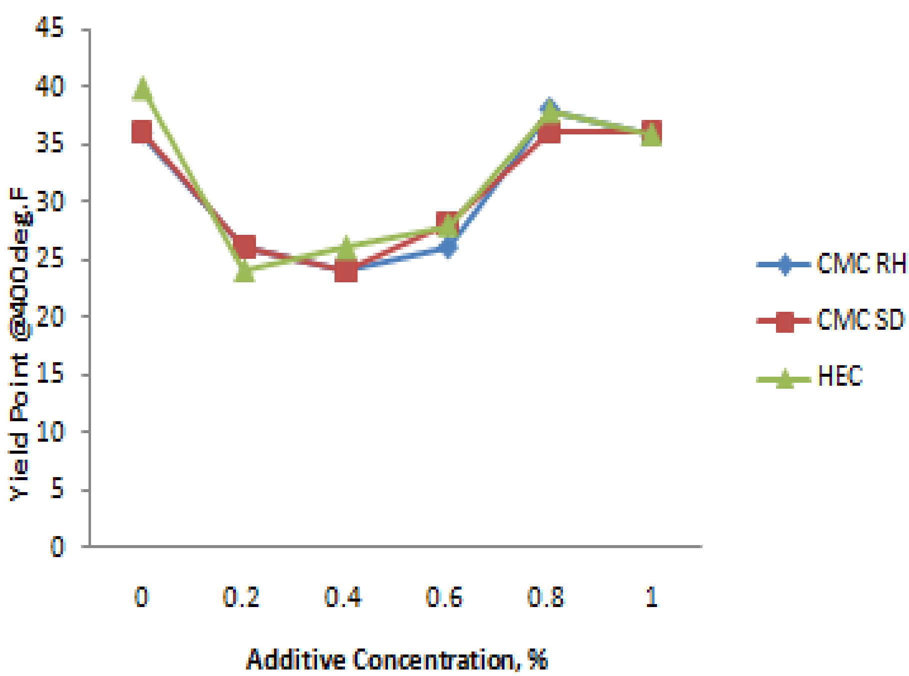

Figure 3: Effect of Additive Concentration on Slurry Yield Point at 400 ^{0}F

The slurry yield point at 500^{o}F as shown in Figure 4 reveals that there was a decline in the yield point till 0.4% before increasing to 1% concentration.

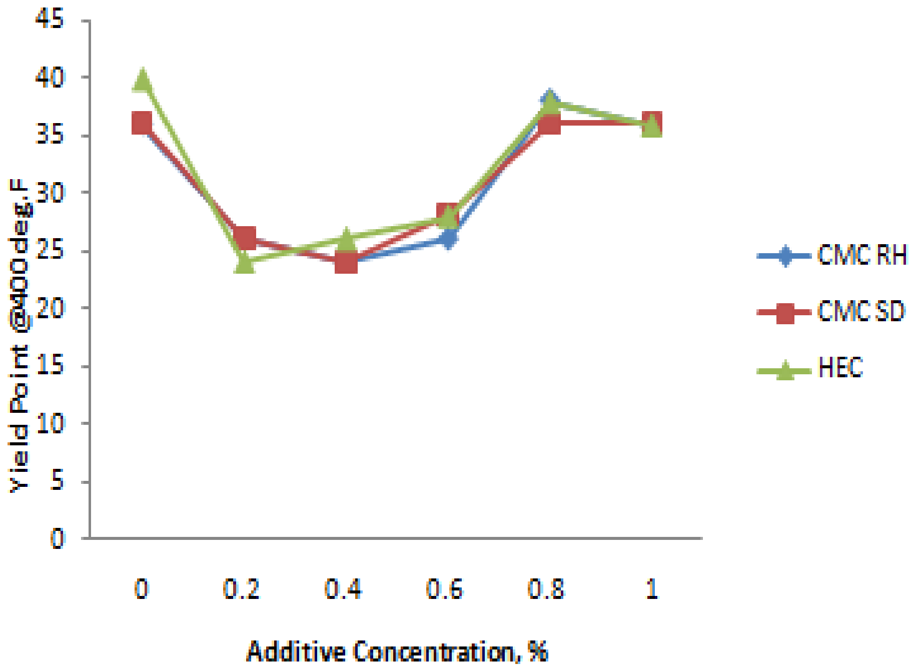

Figure 4: Effect of Additive Concentration on Slurry Yield Point at 500 ^{0}F

Figure 5 shows the slurry yield point at 600^{o}F revealing a continues increase in the slurry yield point after 0.2% till 1 % concentration.

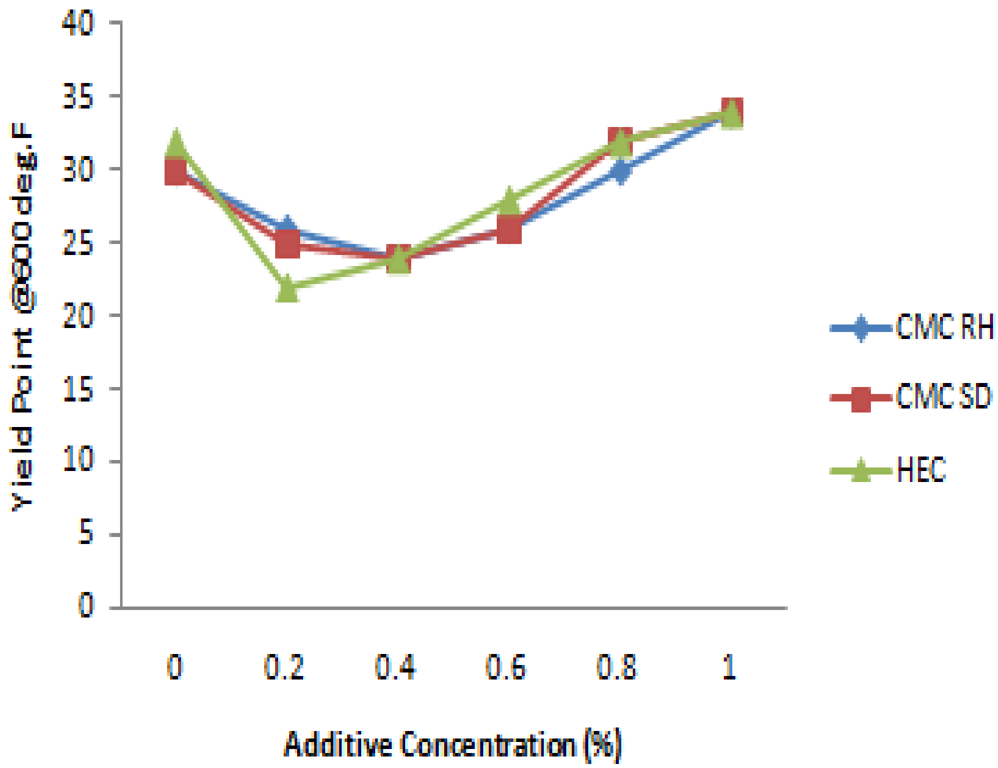

Figure 5: Effect of Additive Concentration on Slurry Yield Point at 600 ^{0}F

A similar though inverse observation was recorded for the slurry plastic viscosity as shown in Figures (6-10) above. At 200^{o}F, there was a consistent decline in slurry plastic viscosity with increasing additive concentration. However, at 300^{o}F, there was a counter trend after initial decline from 0-0.2% additive concentration. This observation did not continue for all other test points. There was a reverse in the behavioral trend similar to the one observed at 200^{o}F. This shows that slurry plastic viscosity is extremely sensitive with temperature changes and may often result to complex trends difficult to predict. The distinct behavior of each additive also relatively did not show consistent observation. This therefore shows that a specific additive could be better at a certain concentration and temperature than others. However, the relative differences in the estimated values present each additive a possible alternative to the other.

Figure 6 shows the plastic viscosity at 200^{o}F for different additive concentration. Increase in additive concentration decreases the plastic viscosity of the cement slurry.

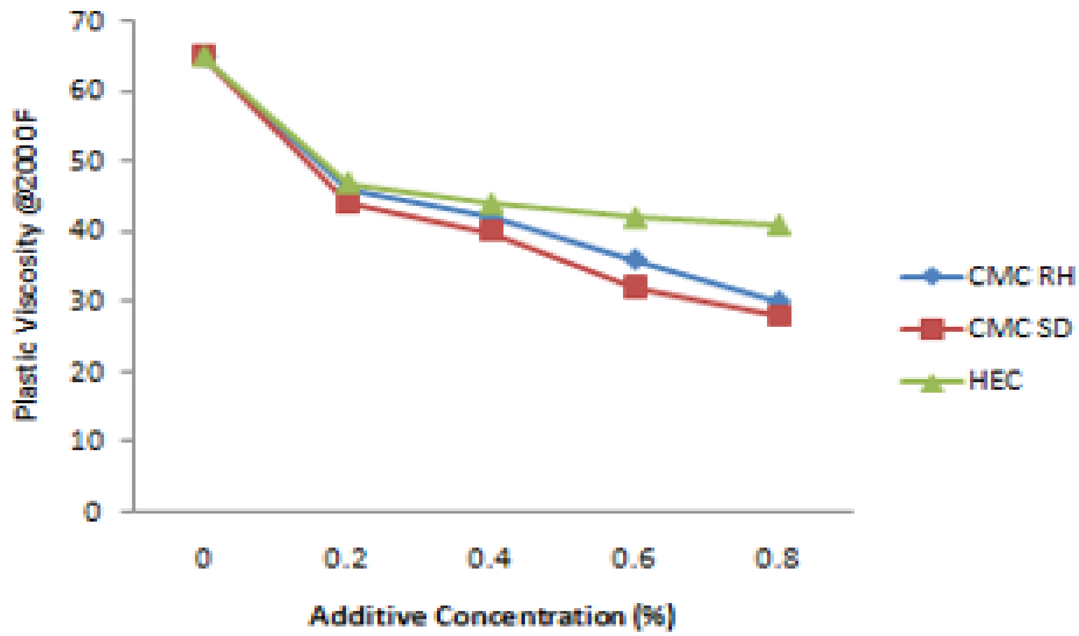

Figure 6: Effect of Additive Concentration on Slurry Plastic Viscosity at 200 ^{0}F

Figure 7 shows the plastic viscosity at 300^{o}F for different additive concentration. Increase in additive concentration increases the plastic viscosity of the cement slurry. Although, a drop was observed at 0.2% before increasing continuously to 1%.

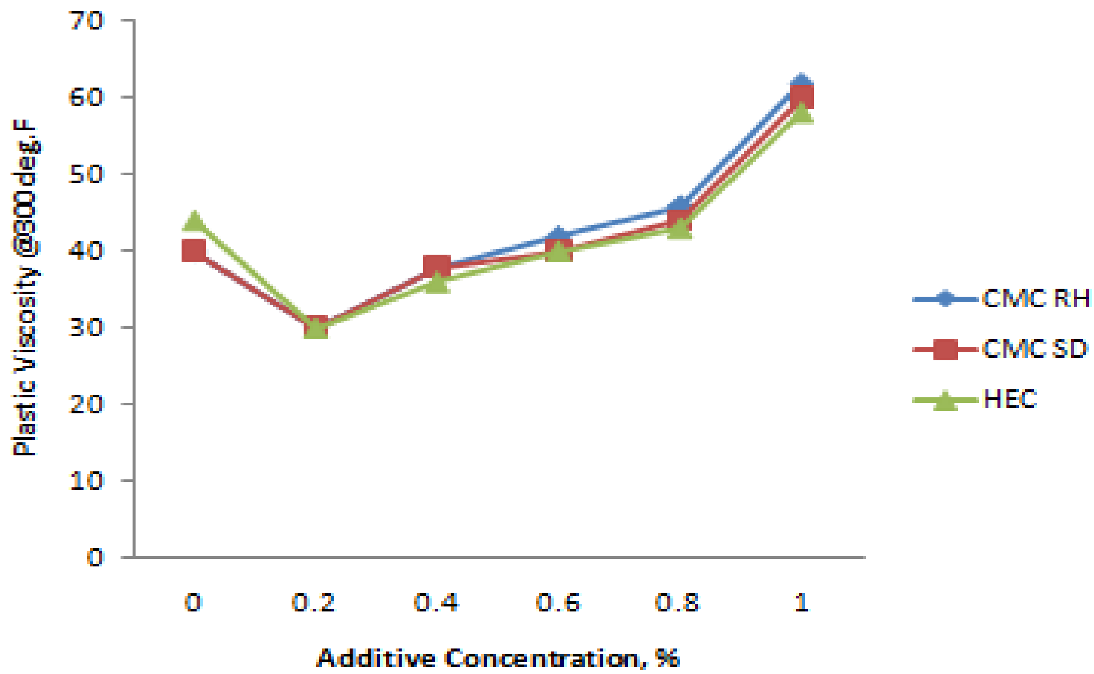

Figure 7: Effect of Additive Concentration on Slurry Plastic Viscosity at 300 ^{0}F

At 400^{o}F, Figure 8 shows an initial drop in the slurry plastic viscosity from 0% to 0.8% before later increasing. There was a little consistency between 0.2 % to 0.8% for different additive concentration.

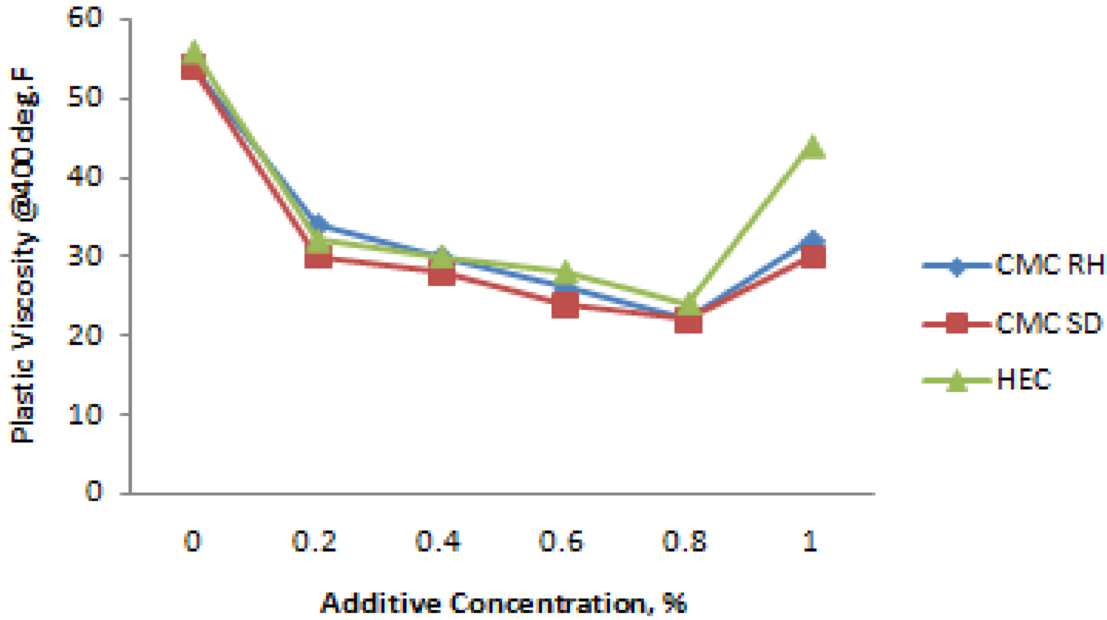

Figure 8: Effect of Additive Concentration on Slurry Plastic Viscosity at 400 ^{0}F

At 500^{o}F, Figure 9 shows an initial drop in the slurry plastic viscosity from 0% to 0.8% before later increasing. There was a little consistency between 0.4 % to 1% for different additive concentration. Figure 10 of 600^{o}F shows similar trend with that of 500^{o}F with a continuous decline in the slurry plastic viscosity as the concentration increases.

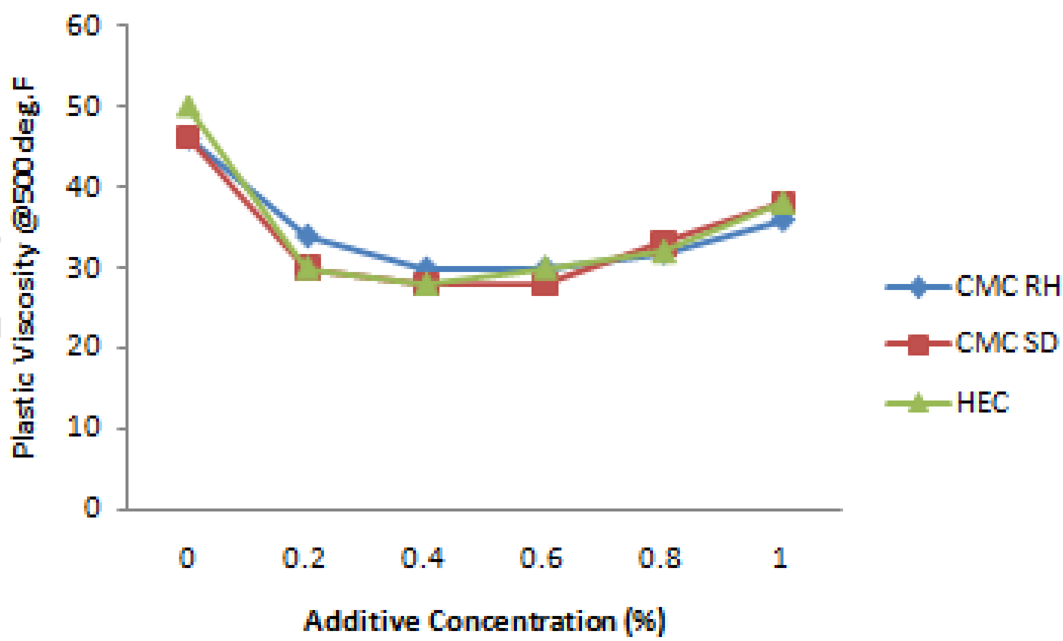

Figure 9: Effect of Additive Concentration on Slurry Plastic Viscosity at 500 ^{0}F

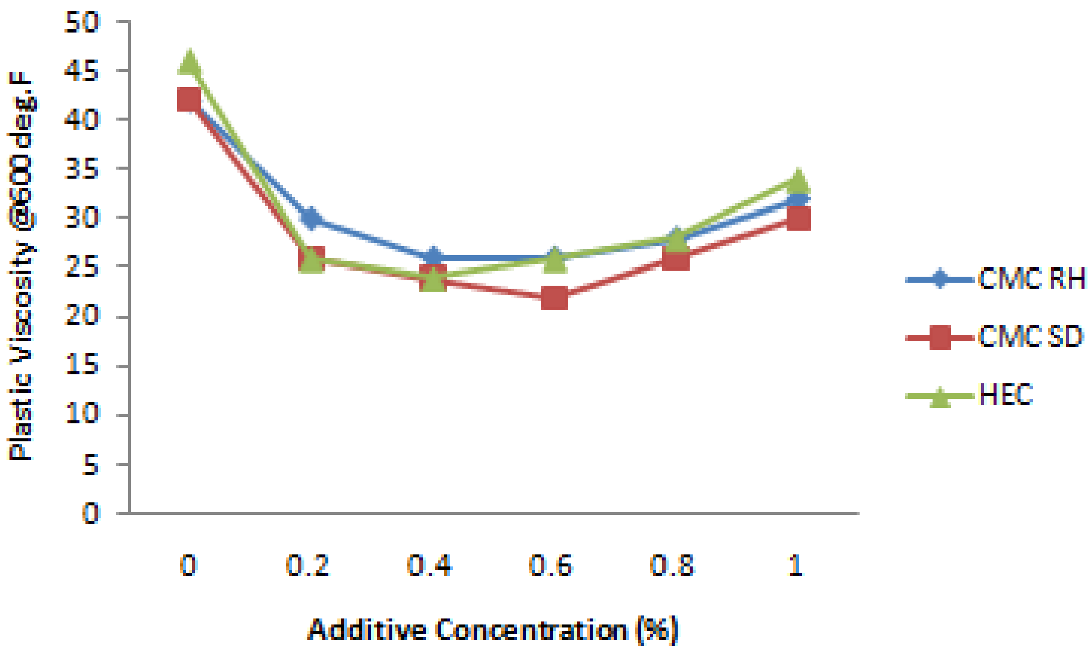

Figure 10: Effect of Additive Concentration on Slurry Plastic Viscosity at 600 ^{0}F

4. Conclusion

The suitability of CMC derived from rice husk and saw dusts (local additives) as a possible replacement for the conventional Hydroxyethyl Cellulose (HEC) additive for designing cement slurry for high temperature and pressure wells was investigated. The results clearly present the Carboxymethyl Cellulose (CMC) derivatives as good alternatives as shown by the competing performance of the additives which are clearly analyzed in results of this study. In a summary, the following performance trends were noted:

i. Increasing the additive concentration increases the rheological performance of the additives at each test temperature

ii. Higher temperature facilitates slurry mixing as shown in free fluids results in which the CMC additives showed better performance than HEC.

iii. The analysis of the two CMC additives shows that CMC from rice husks has some considerable advantage over those of saw dusts as a result of possible contaminants and bio-influencing materials and availability.

References

[1] Arjomand, E., Bennett, T., & Nguyen, G. (2018). Evaluation of Cement Sheath Integrity Subject to Enhanced Pressure. *Journal of Petroleum Science and Engineering* .

[2] Bosma, M., Ravi, K., van Driel, W., & Schreppers, G. (1999). Design Approach to Sealant Selection for the Life of the Well. *SPE Anual Technical Conference and Exhibition.*Houston,Texas: SPE.

[3] Bett, E. (2010). Geothermal Well Cementing Materials and Placement Techniques. *Geothermal Training Programme-Report* , 10:99-130.

[4] Bois, A., Gamier, A., Galdiola, G., & Laudet, J. (2010). Use of a Mechanistic Model to Forecast Cement-Sheath Integrity. *SPE Drilling and Completion, 27* , 303-314.

[5] Broni-Bediako, E., Joel, O., & Ofori-Sarpong, G. (2016). Oil Well Cement Additives: A Review of the Common Types. *Oil and Gas Research* , 112.

[6] Cowan K.M. & Eoff L (1993) Surfactants: Additives To Improve the Performance Properties of Cements, Society of Petroleum Engineers. International Symposium on Oilfield Chemistry New Orleans LA. USA 317-327

[7] Calvert, D.G. Preface. (2006). In: Nelson, E.B. and Guillot, D. (Ed.), Well Cementing, Schlumberger, Texas, 1-11

[8] Gray, K., Podnos, E., & Becker, E. (2009). Finite-Element Studies of Near-Wellbore Region during Cementing Operations. *SPE Drilling and Completion* , 127.

[9] Jianjun, L & Xianbin Y. (2012). Stress Analysis on the Combination of Casing- Cement Ring Surrounding Rock Considering Fluid-Solid Coupling. EJGE Vol.17. Bund,J. pp.1683- 1692

[10] Magarini P, Lanzetta C. & Galletta A. (1999) Drilling Design Manual Eni-Agip Division 97-107

[11] Gazulo,H.(2006).Remedial cementing in well cementing .second edition ..Erik B.Nelson and Veronique-Berlet-Gouedard, chap 14,503-543.sugarland, Texas, U.S.A; Schlumberger

[12] Griffith, J., Lende, G., Ravi, K., Saasen, A., Nodland, N., & Jordal, O. (2004). Foam Cement Engineering and Implementation for Cement Sheath Integrity at High Temperature and High Pressure Wells. *SPE Drilling Conference.* Dallas, Texas: SPE.

[13] Ramos, R., & Camus, A. (2017). Borehole Cement Integrity - Numerical Simulations under Reservoir Conditions. *Mechanica Computacional* , 193-225.

[14] Li, Y., Liu, S., Wang, Z., Yuan, J., & Qi, F. (2010). Analysis of Cement Sheath Coupling Effects of Temperature and Pressure in non-Uniform in-situ Stress Field. *International Oil and Gas Conference and Exhibition.* Beijing, China.

[15] Zheng, S., Frederick, E. B. & Kegang, L. (2014) The Mechanism of Wellbore Weakening in Worn Casing-Cement-Formation System. Journal of Petroleum Engineering 2014: 8.

[16] Shahri, M., Schubert, J., & Amani, M. (2005). Detecting and Modeling Cement Failure in High-Pressure/High-Temperature (HP/HT) Wells Using Finite Element Method (FEM). *International Petroleum Technology Conference*. Doha, Qatar: SPE.

[17] Lavrov, A., & Torsæter, M. (2016). *Physics and Mechanics of Primary Well Cementing*. Springer