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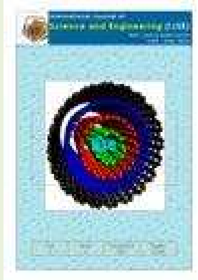

Utilization of Agarwood Distillation Waste in Oilwell Cement and Its Effect on Free Water and Porosity

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Abstract - Common problem during oilwell cementing is free wáter separation. This problem could weaken cement at the top, gas migration problem and non uniform density of cement slurry that are even worst in cementing deviated well. Another concern on cementing design is the porosity of the hardened cement. If the cement is too porous, it can lead to gas migration and casing corrosion. The intent of this research was to utilize the waste produced by distillation process of Agarwood oil and convert it into a profitable oilwell cement additive. All tests were conducted according to API Specification-10B. Free water test was determined at different concentrations of Agarwood Waste Additive (AWA), different inclination angles and different temperatures. Based on the findings, it was observed that zero free water was produced when 2% BWOC of AWA was used at all angles. The findings also revealed that AWA can maintain good thermal stability as it could maintain zero free water at increased temperature up to 60°C. The porosity of AWA cement was comparable with standard API neat cement as the porosity did not differ much at 2% BWOC of AWA. Therefore, it can be concluded that the AWA is suitable to be used as an additive in oil well cement (OWC) with 2% BWOC is taken as the optimum concentration.

Key words - Oilwell cement, Agarwood waste, free water, porosity, inclination angle

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Introduction

Well cementing is a process whereby the annulus between the formation and well casing is pumped with cement slurry. It is done to provide zonal isolation in oil, gas and water wells [1]. During cementing, the cement slurry that is pumped must remain as a pumpable fluid until it reached the intended settling place. A good hydraulic seal should be established between the área of cement and the formation as well as between the casing and the cement to prevent fluid channels in the cement sheath. The well may not reach its full producing potential without a complete zonal isolation in the wellbore [2]. The cementing systems for zonal isolation of wellbore nowadays often require complex design. This is vital in order to attain high cement performance for a specific well condition [3]. Cement slurry that has poor quality can lead to cementing problem and the process of squeeze cementing may generate additional time and cost. A high quality of cement will ensure a lasting stability of the borehole [4]. The other functions of well cementing are to support the casing by protecting the casing from the shock loads when drilling deeper and also protects casing from corrosion [5]. The cement must be able to provide strength and reinforcement to the casing. Therefore, suitable additives need to be added in the cement slurry to achieve the desired performance.

The components and the additives present in the cement slurries influenced the properties and behavior of the cement slurry. Free water is defined as separation of water from cement slurry [6]. As the cements hardens, it is important not to have excess of water at the top of the cement. When slurry is settling, the water may escape from the slurry. The cement slurry has to be an extremely stable suspension with very little free wáter during settling. Free Water will create channels on the high side of cement column which could compromise zonal isolation. Incomplete zonal isolation may result from upward migration of water and the accumulation of water at the top of the cement column. This phenomena may accelerate corrosion problem and gas migration. Cement slurries with high levels of free fluid (normally more than 2% of the slurry volume) often tend to segregate or settle out under static and/or dynamic conditions. As such, it is important to successfully design the cement slurry in order to enable the free water to be kept at minimum level. According to API (2009) [7], the amount of free water should not exceed 3.5 ml.

Gas leakage is one of the problems caused by the hydraulic pressure that falls below the formation pore pressure due to the unconsolidated cement slurry [8]. It is not only dependent on the mechanical strength of cement based materials, but also its durability is affected by the volume and size distribution of cement pores. The porosity of hardened oil well cement (OWC) slurry depends on a number of factors such as the wáter to cement ratio, degree of hydration, type of cement, mixing conditions, chemical additives and mineral additives. It was reported that the increased amount of fiber in latex modified cement could lead to the increment of cement porosity and permeability [1].

Advancement on new drilling technologies requires a lot of investment on the capital cost to the oil and gas company. The capital costs incurred include cementing casing, casing accessories, coring, drillstem testing, logging and etc. For that reason, discovering a suitable substance to be utilized as a new cement additive that can be bought cheaply and also biodegradable is essential to reduce the capital cost. Most important the material must be able to fulfill the API Specification for cement additives. There are several cement properties that need to be evaluated before selecting a suitable additive for cement circulation. One of it is the free water separation. Good cement requires low free water in order to keep the water from escaping to the surrounding formation [9].

Agarwood or its scientific name is Aquilaria Malaccensis can be found in the South and Southeast Asia [10]. Due to the increasing numbers of extraction process for Agarwood oil, the number of Agarwood waste from distillation process is also increasing. Typically, the waste is thrown away as a valueless product. The intention of this research is to investigate the potential of using the waste from distillation process of Agarwood oil as oilwell cement additive. It has been known to public that re-usable the waste product may help to reduce pollution and protect the environment. The waste can be used as alternative cement additive to reduce the capital cost of well completion.

Materials and Methods

Preparation of Agarwood Waste Additive (AWA)

The Agarwood waste was washed and dried up at temperature of 90˚C for 24 hours in an oven before grinding in a cutting mill. The Agarwood waste was then sieved using sieve shaker to get the size of 250 μm before added to the cement slurry.

Mixing Procedure

The cement slurry was prepared by mixing the Class G cements, AWA and water into a mixer. 300 ml of cement slurry was prepared. First, the mixer was operated at 4000 rpm for 15s. Then the slurry was mixed at 12000 rpm for 35s. Slurries with different concentrations of AWA prepared as shown in Table 1. The processes were done following procedures in API Spec. 10B.

Table 1. Formulation of AWA cements

Sample No.	Cement (g)	Mix Water (ml)	AWA (%BWOC)
1 (Neat Cement)	400	176	0
2	400	176	1
3	400	176	2
4	400	176	3
5	400	176	4
6	400	176	5

Free Water Test

The prepared cement slurries were inserted into a 250 ml graduated cylinder at ambient condition to test the separation tendency. The volume of water separated from the slurry was measured after the two hours time. The top of the cylinder was covered with aluminum foils to avoid evaporations. The process was done following procedures in API Spec. 10B and the allowable amount of free water level is 3.5 ml. The tests were performed at the following parameters:

- Different Amount of AWA

Cement slurries of 1% to 5% BWOC of AWA were prepared before they were put into graduated cylinder. The free water levels were taken after two hours in vibration free and ambient conditions.

- Different Directional Angle

Cement slurries were prepared to simulate inclination angle during cementing deviated well. The angles used were 15˚, 30˚, 45˚ and 60˚. The free water levels were taken after two hours in vibration free and ambient conditions

- Different Temperature

Cement slurries were prepared to perform experiment at different temperatures. The cylinders were put into an oven. The temperatures were set to 28˚C (ambient) and 60˚C. The free water levels were taken after two hours.

Porosity Test

Cement slurries were cured in a two by two inches mould for five days. Then, the cement cubes were dried up at temperature of 90˚C for 24 hours in an oven to remove moisture. The weights of the cubes were taken before and after being immersed in a 1000ml beaker for 1 hour. The formulas involve in calculating porosity are as follows:

Pore Volume = [Wet weight – Dry Weight] / Density of Water

.... (1)

$$\theta = [\text{Pore Volume} / \text{Bulk Volume}] \times 100\% \qquad \text{.......................(2)}$$

Results and Discussion

Effects of Agarwood Waste Additive (AWA) on free water at different AWA concentrations, inclination angles and temperatures

Effect of adding different amount of Agarwood waste additives (AWA) was analyzed. Figure 1 shows the results when different amount of AWA was used in the cement slurry. It can be seen that 2%, 3% and 4% BWOC of the AWA produced zero free water level in the cement slurry. The free water level decreased when AWA was added as compared with the neat cement slurry which produced 3.2 ml of free water. As 1% BWOC of AWA was added, the level of free water dropped to 1.6ml. Then, zero free water was obtained when 2 to 4 %BWOC of AWA were added. However, the free water level increased when 5% BWOC of AWA was added.

The volume of produced free water from the cement slurry was affected by the different amount AWA in each of the cement slurries that would result in different consumption of water and rate of reaction. When too little AWA is added which was lower than 2% BWOC, there will be some water left that does not react with either cement particle or AWA particle. Between 2% to 4% BWOC of AWA were added, zero free water level were observed. This showed that AWA had the tendency to absorb water. By increasing the AWA concentration, free water level was reduced. Furthermore, during the mixing, some particles in AWA would fill the pores between the cement grains. This will delay the reaction of cement with water thus trap some of the water. However, when too much particles of AWA presented in the slurry which was greater than 4% BWOC, there would be an increase in free water level. This is due to the reaction between cement and AWA itself where the AWA particles filled the cement pores and prevent the reaction of cement and water.

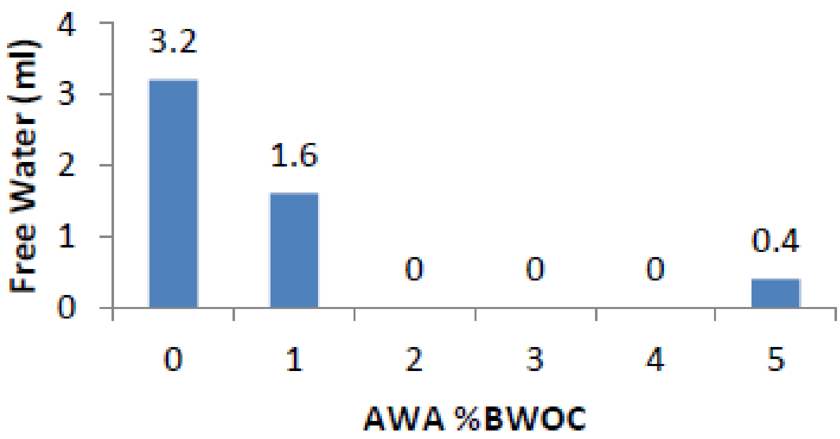

Figure 1. Effect of Different %BWOC of AWA to Free Water

Effect of different inclination angles for directional well to free water has been observed. Table 2 illustrates the amount of free water produced when different inclination angles were used. The angles used are 15˚, 30˚, 45˚ and 60˚ as shown in Figure 3. From Figure 2, it can be observed that when the angle was less slanted, the amount of free water produced increased. However this is only for 3% to 4% BWOC of AWA. For 2% BWOC of AWA, zero free water was observed for all the tested angles.

As the angle was less slanted, there will be shorter distance for the water to migrate to the surface. Therefore it is easier for free water to be produced. This phenomenon can be illustrated as a pocket water. Pocket water is found at the topside of the cement slurry that can lead to the corrosion of the drilling equipments and also formation damage. The more slanted the angle, the lesser amount of free water produced.

The effect of the temperature to the cement slurries with AWA was also tested and the results are shown in Table 3. .By increasing the temperature to 60˚C, the levels of the free water remains at zero with comparison at ambient temperature (28˚C). This proved that by adding AWA by 2% to 4% BWOC to cement slurries can avoid free water until 60˚C.

Table 2. Effect of Different Inclination Angle to Free Water

Inclination Angle (θ)	**15**			**30**			**45**			**60**		
AWA (%BWOC)	2	3	4	2	3	4	2	3	4	2	3	4
Free Water (ml)	0	0	0	0	0	0	0	0.1	0.2	0	1.2	2.2

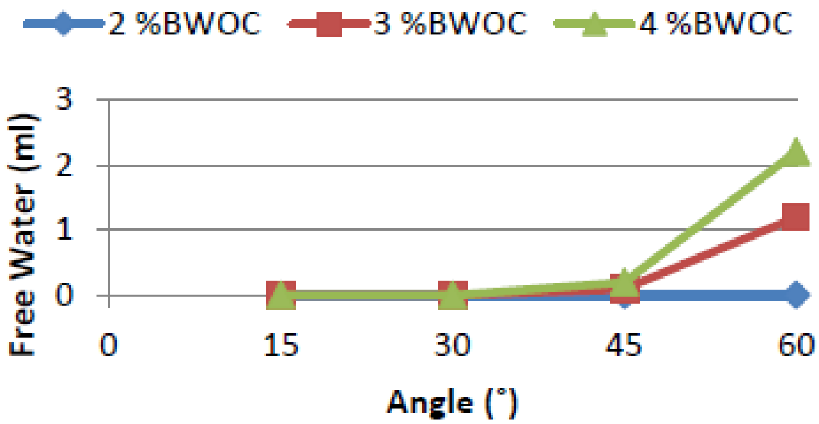

Figure 2. Effect of Different Inclination Angle to Free Water

Figure 3. Position of Cylinder for Directional Angle

Table 3. Effect of Different Temperature to Free Water

AWA (%BWOC)	2		3		4	
Temperature (°C)	28	60	28	60	28	60
Free Water (ml)	0	0	0	0	0	0

Effects of Agarwood Waste Additive (AWA) on cement porosity at different AWA concentrations

The effect of different % BWOC of AWA was also tested on porosity. The porosity results show an increase pattern when 2% to 4% BWOC of AWA were added in cement slurries as shown in Table 4 and Figure 4. By comparing to the porosity of neat cement slurry and the porosity of 2% BWOC of AWA, the difference was very little and it could be considered as acceptable value for producing a good cement seal. However, the increments of porosity were too large when comparing with 3% and 4% BWOC of AWA. A large pore size can easily allow the water to escape faster. The other problem that can be related with large pores is gas migration whereby the gas that enters into the cement may disrupt the matrix of the cement.

Table 4. Effect of Different %BWOC of AWA to Porosity

AWA (%BWOC)	0	2	3	4
Dry weight (g)	203.36	193.38	194.64	193.90
Wet weight (g)	219.14	210.14	213.72	220.60
Pore Volume	15.78	16.76	19.08	26.70
Bulk Volume	100.00	100.00	100.00	100.00
Porosity	0.16	0.17	0.19	0.27

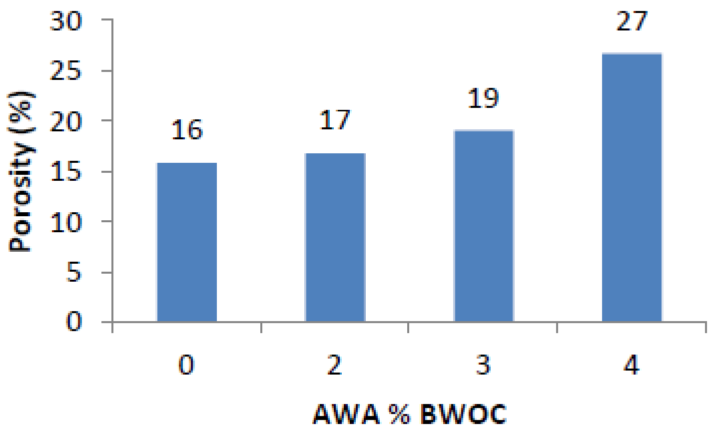

Figure 4. Effect of Different %BWOC of AWA to Porosity

Conclusions

The conclusion that can be drawn from the study is that the Agarwood waste additive (AWA) can be used as an additive to the oilwell cement. The free water level of the cement slurry when added with 2 to 4 %BWOC of AWA resulted in zero amount. For directional angle simulation, the results showed that the volume of the free water produced is zero for low deviated well. For temperature difference, zero level of free water was obtained when the temperatures are 28°C and 60°C. Nevertheless, the free water level for all tests are below 3.5 ml which is the maximum allowable free water level according to API 10B. For porosity test, cement formulation with 2% BWOC of AWA was comparable to the porosity of neat cement slurry. Therefore, 2% BWOC of AWA is chosen as the optimum concentration of AWA in oilwell cement slurry due to the zero free water level produced at all tested conditions.

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