Rheological Study of Oil Palm Trunk Waste as Viscosifier Agent for Water-Based Mud

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Abstract. The cellulose obtained from Oil Palm Trunk (OPT) is used to determine its potential as a viscosifier agent for the Water-Based Mud (WBM). The cellulose was extracted by using two methods which are Method 1 (Chlorination-Bleaching Process and Mercerization Method) and Method 2 (Dewaxed-Alkaline-Delignification Method). The characterization of OPT cellulose is defined by FTIR while the content of the cellulose product is determined by the Weighting Method.

The mud samples were formulated by the presence of different weight of cellulose applied. The rheological properties analysis was conducted on the viscosity (PV), gel strength, yield point (YP) and, filtrate volume. FTIR Spectrometry results showed that Method 2 mimicked the behavior of HEC cellulose (commercial product). Method 2 produced cellulose which has a similar functional group that appears at the same spectral peaks with HEC cellulose.

On the yield percentage, Method 2 yields more cellulose by 43.05% while Method 1 only yields 37.63% of cellulose. While the results from the rheological analysis summarized that cellulose obtained from Method 2 portrays a good range of results as it met the standard range of PV for the WBM by API Recommended Practice 13B-1. In conclusion, the cellulose extracted from Method 2 has the potential to be commercialized as a viscosifier agent for WBM.

Keywords — Cellulose, Oil palm trunk (OPT), Rheological properties, Water-based mud (WBM).

1. Introduction

According to the American Petroleum Institute, drilling fluid is defined as circulation fluid used in the drilling operation to clean the wellbore from drilling cuttings [1], acts as cooling and lubricant agents to the drill string and drill bit. There are 3 major types of drilling fluids; Water-Based Mud (WBM), Oil-Based Mud and Synthetic-Based Mud. The WBM has the advantages of possessing the shear thinning property, high true yield strength, good bit hydraulics, able to reduce circulating pressure losses, improve borehole stability and economical, and eco-friendly [2]. The additives such as viscosifiers, viscosity reducers, weighting materials, and pH control additives are needed in designing the WBM to enhance the rheological properties, cater to the different drilling operations. The common commercial polymers used as additives for WBM fluid are Carboxy-Methyl Cellulose (CMC) and Hydroxy-Ethyl Cellulose (HEC) [3].

On another hand, a plant derivative-additive for WBM can be formulated using cellulose. Cellulose has a high-water absorption capacity. Hence, having a higher concentration of cellulose can increase the viscosity of the drilling fluids. Cellulose is a renewable polymer resource and the cellulose apparent is caused by existing lignocellulosic material by being part of woods trunk components [4].

One of the easy-abundant sources of cellulose in Malaysia is from the oil palm trunk (OPT). It is known as a non-wood lignocellulosic material and has a rich content of carbohydrates that form of sugar-containing cellulose, starch, hemicellulose and lignin [5]. The chemical composition of cellulose and lignin in OPT is in the range of 29% to 50%, and 20% to 25% respectively.

The amount of OPT as agricultural waste material in Malaysia is increasing with the rapid growth of the palm oil industry [6], causing another problem in waste management. Hence, in this study, the local OPT is selected as the cellulose source to formulate the cellulose-based viscosifier for WBM, focusing
on the effect of the different weight towards the rheological properties of the WBM, and its performance is compared to the HEC-polymers (commercial viscosifier agent).

2. Materials and method

2.1. Sample preparation

The OPT waste was obtained from the Forestry Research Institute of Malaysia (FRIM). The sample was dried in an oven at a temperature of 70°C for two days. It was then milled and sieved to the range of 710-150 µm sizes.

2.2. Selection of methods for cellulose extraction

There are two methods for cellulose extraction applied in this study.

Method 1: A Chlorination-Bleaching Process and Mercerization Method. 4ml (5%) acetic acid and 8g Sodium Chlorite (NaClO₂) were added to the beaker containing 20g of 500µm-sized OPT sample and was left overnight. The sample later was rinsed to remove the yellowish residue and was rinsed until it became odorless. The sample (holocellulose) was soaked with 80ml (17.5%) Sodium Hydroxide (NaOH) and further treated with 120 ml NaOH for the total treatment time of 45 minutes. 240ml distillation water and 800ml (8.3%) NaOH were added into a beaker containing a sample and were stirred constantly for 5 minutes. The alkaline cellulose was rinsed up with distillation water and cleaned up with (10%) of acetic acid. The sample was again filtered, washed, rinsed and then was dried overnight in the oven at 80°C. The chemical purified cellulose (CPC) obtained from this method is characterized by using FTIR.

Method 2: A Dewaxed-Alkaline-Delignification Method. 5.8g of the sample was used in this removal lignin treatment by using a Soxhlet apparatus with toluene-ethanol (2:1, v/v). The process took about 6 hours at 100°C. The powder obtained was let dry for 2 days at room temperature. The delignification treatment with NaClO₂ was conducted at 75°C for 1 hour. The product was then treated with 2wt% Potassium Hydroxide (KOH) and 5wt% KOH at 90°C, filtered and rinsed until achieved pH~7 to obtain the CPC. This CPC is also characterized by using FTIR.

2.3. WBM preparation

The mixing solution of 10g bentonite with 350ml of tap water was left overnight. All additives; Sodium Chloride (NaCl), Xanthan Gum, NaOH and, Barite were added later, together with the different weight of OPT cellulose for each mud samples.

3. Results and discussion

3.1. The yield percentage of extraction cellulose from OPT wastes

Method 1 and Method 2 applied the delignification process to extract the cellulose from OPT waste using a total of 40g of OPT sample. Table 1 showed that the yield percentage of cellulose from Method 2 is higher than Method 1. The significant difference in Method 2 and Method 1 is, there was a heating process involved in Method 2 and not in Method 1. The heating process makes the extraction more efficient in separating the cellulose from the other components (lignin, etc.) in the OPT sample. The percentage of lignin and other components in OPT sample is 56.95% and 62.40% for Method 1 and Method 2, respectively and these values are supported by the previous study which stated that the percentage range of delignification process will remove 56-62% of other components (lignin etc.) from the OPT [7].

| Extraction method | Method 1 | Method 2 |
|-------------------|----------|----------|
| Weight of OPT (g) | 40.0     | 40.0     |
| Final weight of cellulose (g) | 15.05 | 17.22 |
| Percentage yield cellulose (%) | 37.6 | 43.05 |

3.2. The FTIR spectrometry results
Figure 1 (a), (b) and (c) show the results analysis of OPT and HEC cellulose by using FTIR spectrometry. One of the characterizations of cellulose is based on the presence of the OH functional group which can be observed at the range 3400-3200 cm\(^{-1}\) [8]. The same peak at the range of 3400-3200 cm\(^{-1}\) was observed in all samples. However, the transmitted intensity value is slightly different i.e. 82% (Method 1), 85% (Method 2) and 91% (HEC).

Another peak detected at the range of 3000-2800 cm\(^{-1}\) for Cellulose-Method 2 and HEC, but not for Cellulose-Method 1. This peak defined the CH-stretching vibration which is corresponded to the C-H stretching vibrations and the aliphatic parts in polysaccharide (cellulose and hemicelluloses). At the range of 1400-1100 cm\(^{-1}\), there is another absorption spectral band peak for Cellulose-Method 1 and 2; which represents the CH deformation in cellulose and hemicellulose, vibration of C-O-C in cellulose and hemicelluloses, and vibration of CO in cellulose and hemicelluloses.

The CH deformation in cellulose and hemicellulose was not occurred in HEC, knowing that cellulose from HEC is a derivative-typed of cellulose which is a stable form in the HEC, thus make the HEC perform better as an additive in WBM. Overall, the spectral bands observed from cellulose obtained Method 2 is similar with the cellulose in HEC, hence it can be concluded that the properties of cellulose obtained Method 2 is slightly the same as the HEC commercial.

3.3. Water-based mud rheological analysis

The rheological analysis (plastic viscosity, yield point, gel strength, mud weight and, pH was conducted to observe the behavior of WBM, focusing on the effects of the different weights of cellulose.

3.3.1. Mud weight and pH results. Three different weights of OPT cellulose and commercial cellulose (4g, 6g and, 8g) were used in this rheological test. The mud weight is kept constant at 9.70ppg as referred
to API drilling mud production standards [9]. Table 2 shows the results of mud weight and pH test of the formulated WBM.

Table 2. Mud weight and pH of WBM.

| Parameter/Weight Method | 4g  | 6g  | 8g  |
|-------------------------|-----|-----|-----|
| **Mud Weight (ppg)**    |     |     |     |
| Method 1                | 9.7 | 9.7 | 9.7 |
| Method 2                | 9.7 | 9.7 | 9.7 |
| HEC                     | 9.7 | 9.7 | 9.7 |
| **pH**                  |     |     |     |
| Method 1                | 10.74 | 10.48 | 11.55 |
| Method 2                | 10.75 | 10.8 | 11.56 |
| HEC                     | 10.8 | 10.9 | 11.6 |

As the weight of OPT cellulose and HEC commercial cellulose were increased. The mud becomes more alkaline as the weight of cellulose increased, due to the presence of OH functional group as shown in the FTIR result and both methods show almost the same value as HEC commercial cellulose.

3.3.2. Plastic Viscosity (PV). The plastic viscosity is a slope of shear stress against shear rate, representing the viscosity of mud. It can be calculated from the dial reading of 600 rpm and 300 rpm. Figure 2 shows the effects of different weights on plastic viscosity behavior.

![Figure 2. Effects of different weight of cellulose on PV behavior.](image)

The PV value represents the intermolecular interaction due to hydrophobic alkyl substituents which affect the flow behavior (viscosity properties) [10]. For 4, 6, 8g of cellulose, the PV values from Cellulose-Method 1 and 2 are about in the optimum range of PV which is between 16cP to 22cP [9]. But for HEC, the PV is quite high for the selected weights.

3.3.3. Yield Point (YP). Based on Figure 3 below, Cellulose-Method 1 and 2 show an increment trend of YP from 47.4 to 85.7 (lb./100ft²) and from 45 to 59 (lb./100ft²) respectively as the weight of OPT increased from 4g to 6g. However, the YP performance starts to decrease when the weight is increased to 8 g cellulose increased from 6g to 8g. The HEC 1 gives a high value of YP compared to Method 1 and Method 2. Theoretically, the increment of YP values affected by the increase of the viscosifier’s weight or concentration (as supported by [9]). The viscosifier agent such as HEC will re-arrange and react with the presence of water and other additives in WBM. Hence, the viscosity will increase in parallel with YP values.
3.3.4. Gel strength. The gel strength refers to the shear stress required to initiate flow after static periods. In this study, the gel strength taken at the time of 10 minutes. The results from Figure 4 shows that the increasing weight of cellulose will also increase the gel strength values. Theoretically, the increasing value of gel strength will ease the drilling fluid capability to suspend the cutting during no flow and to circulate the cutting to the surface. However, if the value of gel strength is beyond the recommended value, it will affect the capability of drilling fluid to pump the cutting out to the surface from the wellbore [3].

3.3.5. Filtration Test. Measurement of filtration behavior is fundamental to the treatment and the control of drilling fluid [9]. Figure 5 below, shows the filtrate volume of sample muds containing 4, 6, 8g of Cellulose Method 1 and 2, and HEC. The results show that the performance of mud filtration for Cellulose-Method 1 and 2 is decreased when there was an increment in weight of OPT cellulose. Besides, Method 2 shows the fluid loss in WBM decreases from 12.6ml to 12.4ml due to the increased weight of cellulose. The optimum for mud filtration for Cellulose-Method 2 is at 6g. Meanwhile, HEC cellulose has the same trend as Method 2 cellulose in terms of fluid loss from WBM. The optimum mud filtration for HEC cellulose at 9.6ml of fluid loss at 4g weight of cellulose.
Conclusion
This study has achieved two important objectives; study on cellulose extraction (from OPT) method and rheology analysis on the different weight of the extracted cellulose. For the first part, Method 2 (Dewaxed-Alkaline-Delignification Method) yielded more percentage of extraction cellulose from OPT waste compared to Method 1 (Chlorination-Bleaching Process and Mercerization Method). The characterization of cellulose has been done successfully by using FTIR Spectrometry which resulted in a term of functional group that represents the existence of cellulose itself. For the second part, the results from cellulose extracted from OPT were compared with the commercial viscosifier; HEC. For PV value, the Cellulose-Method 2 portrays a good range of results as it met the standard range of PV for the WBM by API Recommended Practice 13B-1. Also, it shows its best value (21.3cP) at a weight of 8 g. While for HEC cellulose despite showing the highest PV value; the PV value does not meet the range of PV standard for WBM. Based on the YP behavior test, Method 2 also shows the best yield point results at 6g weight of cellulose compared to Method 1 and HEC commercial. Next, the gel strength test shows that the gel strength values are increased by increasing the weight of OPT and HEC cellulose. Overall, OPT cellulose (Method 2) shows the best performance in this rheological test. Thus, the objective to analyze the effects on rheological properties by applied different weight of OPT waste and HEC commercial are achieved. It can be concluded that cellulose extracted from Method 2 has the potential to be commercialized as a viscosifier agent for WBM.

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