The Influence of Lignocellulosic Fiber from Oil Palm Trunk Waste on Drilling Fluid Filtration Properties

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Abstract— **Lost circulation and fluid loss are amongst the common problems encounter during drilling operation. The loss of mud and filtrate into formation could result in formation damage. Amongst the known formation damages are reduce in permeability and porosity in the near wellbore zone. Hence, an investigation was conducted on Oil Palm Trunk (OPT) fiber that have potential to act as fluid lost control (FLC) agent and lost circulation material (LCM). Rheology test and API filtration were performed to evaluate the performance of OPT fiber added drilling mud as FLC. Sand bed test was performed to evaluate the performance of OPT fiber added mud as LCM. For the API filtration test, addition at increase amount of OPT fiber did reduce the filtrate loss. The filter cake thickness increases as higher amount of OPT fiber was used in the drilling mud. The use of smallest size of OPT fiber (<75µm) yield the lowest fluid loss. For the sand bed test, mud invasion is reduced as the concentration of OPT fiber used increases. It was also found that, the OPT fiber with the size of 75µm to 150µm perform best in reducing mud invasion. Thus, it can be concluded that OPT fiber can be used as FLC or LCM. OPT fiber can be used as FLC as long as filter cake thickness was still within acceptable limit.**

Keywords— API Filtration Test, Drilling Mud, Filter Cake Thickness, Fluid lost control (FLC), Lost Circulation Material (LCM), Oil Palm Trunk Fiber, Sand Bed Test.

I. INTRODUCTION

Fluid loss is the result of filtrate loss from drilling fluid into the formation. Invasion of filtrate into formation could reduce the permeability near the wellbore zone that can lead to lower production. If the filtrate invades the shale section, it can cause the clay swelling that can lead to pipe sticking [1]. In order to prevent or reduce the fluid loss, FLC additive need to be used in drilling fluid. According to [2], there were two basic mechanisms in which fluid loss control can be achieved. First, fluid loss control can be achieved by increasing the overall viscosity of the drilling fluid using water-dispersible polymers such as Carboxymethyl cellulose (CMC), polyanionic cellulose (PAC), hyrdroxyethyl cellulose (HEC). The use of water dispersible polymers have direct impact to drilling mud bulk viscosity.

Second, fluid loss control can be achieved by forming internal or external filter cake to plug the formation pore throats using insoluble material such as calcium carbonate, mica, silica flour. Those materials are insoluble just same as unmodified cellulosic fiber. According to [3], modification is necessary for natural cellulosic fiber to be used as water-dispersible FLC. This is because natural cellulose is insoluble in water. However, several researchers have proved that the use of unmodified cellulosic fiber could achieve the fluid loss control [4], [5], [6], [7], [8], [9], [10] but the result is minimal. According to [7], [8], [11], small and fine particles of insoluble fibers are capable to filled the pore spaces between the filter cake. Therefore, fluid loss can be reduced. Thus, it can be concluded that the use of unmodified cellulosic fiber could also achieve the fluid loss control through the second mechanism. Since the control is achieved physically, it is expected the filter cake thickness will increase as more raw material is used to reduce the fluid loss. Study by [9], [10], [12] shows that as higher amount of raw material used to reduce the fluid loss, the thickness of filter cake was increased.

Loss circulation can be defined as total or partial loss of drilling fluid into the formation [4], [13].Mud losses into formation does have economic impact and causing drilling problems. Mud is accountable for 25 to 40% of total drilling cost [14]. Non-productive time was spent to cure the lost circulation. Lost circulation also lead to poor hole cleaning, increase formation damage and pore plugging [14]. Severe mud losses will lead to well control problems. Total loss of drilling fluid occurred when there was no mud returning to the surface. Partial lost circulation is when volume of mud returned to the surface is less than the volume of mud pumped into the well [4] . In order to cure or prevent lost circulation or mud loss during drilling, lost circulation materials (LCM) can be used in the drilling fluids. There are four types of LCM, which is fibrous materials, flaky materials, granular materials and hydrated slurries [15]. LCM also can be divided into two types which is particulates LCMs and fibrous [14]. Particulates LCMs include granular and flaky materials. Amongst the example of fibrous materials is micronized cellulose, bagasse, sawdust, wood fibers, shredded tyres and paper pulp [15]. Fiber materials are the materials with less rigidity unlike granular materials. The working principle of LCM is simple. As the LCM has been transported to the fractures, the coarse LCM will bridge the fractures to provide the mechanical strength. In case of fiber, it will create the network structure across the fracture. Subsequent seal will be provided by deposition of small particles on top of the bridged or network created. Small particles is attributed to fine LCM or fine clay in the drilling fluid [14].

In this study, Oil Palm Trunk Fiber was used to investigate its potential as fluid loss control (FLC) additive and as loss circulation material (LCM). Oil palm biomass (OPB) can be classified as lignocellulosic wastes [16]. According to [17], OPB can be classified into six types which are oil palm fronds (OPF) and oil palm trunks (OPT) empty fruit bunches (EFB), palm kernel shells (PKS), mesocarp fiber (MF) and palm oil mill effluent (POME). The first two types of OPB commonly been produced at the plantation site while the rest generated from the mill site. The main component of oil palm biomass (OPB) fiber is holocellulose and lignin accounting about (70%-80%) and (17%-25%) of the fiber respectively [18]. According to [19], oil palm-based plywood mills utilized 40% of OPT, the other 60% of OPT is discarded as waste or residue. The residue can be justified as Oil Palm Trunk Waste (OPTW). Free hydroxyl cellulose have strong attraction to solvents and solution and the moisture sorption process is achieved through hydrogen bond [20]. It is expected that, OPT fiber can retain water in drilling mud thus reducing fluid loss. For LCM, it is clear that OPT fiber is wood fiber that can be categorized as fibrous LCM.

II. METHODOLOGY

A. *Preparation of Oil Palm Trunk Fiber*

About one and half sack of Oil Palm Trunk Fiber was obtained from FRIM located at Kepong. The OPT was originated from the core part of the Oil Palm Trunk. The OPT have been milled into large sizes by using milling machine owned by FRIM. The OPT was dried by using oven at 70ºC for 24 hours. Then the dried OPT fiber was grounded into smaller sizes. The sizes of grounded is as per Table 1.

Table1: Classification of grounded OPT fiber

Classification of sizes	Range of sizes
Fine	<75 μm
Medium	75 μm to 150 μm
Medium	150 μm to 250 μm
Intermediate	250 μm to 350 μm
Intermediate	350 μm to 500 μm

B. *Preparation of mud samples*

The materials used to formulate water base mud was formulated by using materials obtained from Scomi Oil Tools Sdn Bhd located at Bukit Jelutong, Shah Alam. The materials were mixed by using Hamilton Beach Mixer. Each additive was added accordingly and mixed for a specific time. Total mixing time was set to 45 min. Table 2 shows the materials' mixing order, additives, amount and mixing time for each additive.

Table 2: The materials mixing order, additives, amount and mixing time

Mixing order	Additive	Amount	Mixing Time
1	Water	250 ml	
2	Soda Ash	0.2 g	2 min
3	KCL	12 g	4 min
4	Starch	5 g	5 min
5	Xanthan Gum	1 g	10 min
6	NaOH	0.1 g	2 min
7	Barite	90 g	5 min
8	OPT fiber	2g, 4g and 6g 2%, 6% and 10%	2 min

As shown in Table 3, sixteen mud samples were prepared for this study.

Table 3: Mud samples prepared for this study

Sample	Sample' composition
Rheology and Filtration Test	
A	Base Mud
B	Base Mud+ 4g <75 μm of OPT fiber
C	Base Mud+ 4g 75 to 150 μm of OPT fiber
C1	Base Mud+ 2g 75 to 150 μm of OPT fiber
C2	Base Mud+ 6g 75 to 150 μm of OPT fiber
D	Base Mud+ 4g 150 to 250 μm of OPT fiber
E	Base Mud+ 4g 250 to 350 μm of OPT fiber
F	Base Mud+ 4g 350 to 500 μm of OPT fiber
Sand Bed Test	
A	Base Mud
G	Base Mud+ 6% <75 μm of OPT fiber (≈ 6.49g)
G1	Base Mud+ 2% <75 μm of OPT fiber (≈ 2.17g)
G2	Base Mud+ 10% <75 μm of OPT fiber (≈ 10.83g)
H	Base Mud+ 6% 75 to 150 μm of OPT fiber (≈ 6.49g)
I	Base Mud+ 6% 150 to 250 μm of OPT fiber (≈ 6.49g)
J	Base Mud+ 6% 250 to 350 μm of OPT fiber (≈ 6.49g)
K	Base Mud+ 6% 350 to 500 μm of OPT fiber (≈ 6.49g)

C. *Rheology Test*

Rheology test was conducted according to API Recommended Practice 13B-1 [21]. Mud weight of the mud samples A to F were measured by using OFITE Mud Balance and were set in between 9 to 12 ppg. The pH of mud samples were determined by using TRANS BP3001 pH meter. The recommended pH is between 9.5 to 12.5 [22] [23].This is because low drilling mud pH will increase the corrosion rate [9]. The plastic viscosity, yield point and gel strength of the mud samples were investigated by using Fann Viscometer 35SA.

D. *API Filtration Test*

Filtration test for mud samples A to F was conducted according to procedure stated in API Recommended Practice 13B-1 [21]. The filtration test was conducted at 100 psi for 30 minutes. After 30 minutes, filtrate volume collected in measuring cylinder was measured. The filter cake thickness was measured in mm unit by using digital vernier caliper. The filtrate volume collected must be less than 15 ml [24] [23]. Filter cake thickness was measured by using digital vernier caliper in mm. The good filter cake thickness should be less than 2/32 inch (≈ 1.6mm) or 2 mm [25] [1].

E. *Sand Bed Test*

Sand bed test was conducted for mud samples A, G1 to K. The procedure for conducting sand bed test was based on [26] [27]. The sand bed test was conducted by using LPLT filter press with clear Plexiglas cylinder. The test was conducted at 100 psi for 30 minutes. After 30 minutes, depth of mud invasion into sand bed was measured. 20/40 frac sand was used as sand bed to simulate formation porosity and permeability. The mud invasion below 5 cm shows the good performance of LCM [7].

III. RESULTS AND DISCUSSION

A. *The effect of increases amount of OPT fiber to filtration properties.*

Figure 1 shows the effect of increased amount of OPT fiber added in drilling mud to fluid loss. It could be observed that the filtrate loss were reduced as the higher amount of OPT fiber added to the drilling fluid. The addition of 2g, 4g and 6g of 75 to 150 μm of OPT fiber have reduced the API fluid loss from 6.5 ml to 5.6 ml, 5.6 ml and 5 ml respectively. The results obtain were in the same trend with the hypothesis formulated based on the literature review. Most of the findings showed that, increase in addition amount of cellulosic fiber used could reduce the fluid loss. Alsabagh et al., observed the reduction of fluid loss from 100 ml to 47ml, 38.8 ml and 29 ml by addition of 1.5%, 3% and 6% of coarse peanut hulls [6]. Okon et al., observed the similar trend. Their study showed that by addition of 5g, 10g, 15g, and 20g thus reducing the fluid loss from 47 ml to 42.5 ml, 35 ml and 24.5 ml respectively [12].

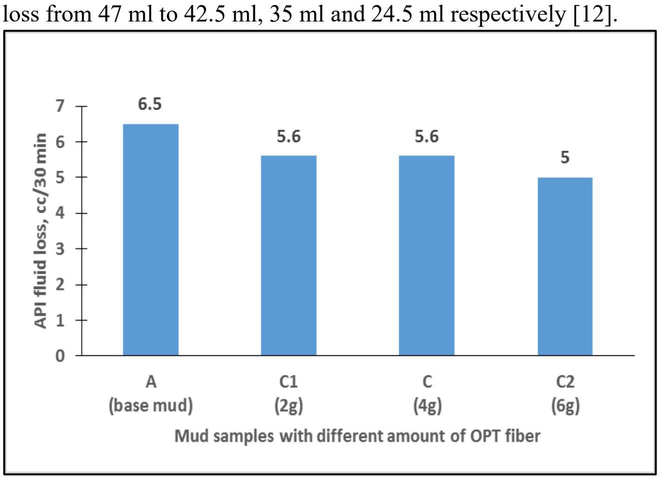

Figure 1: Effect of increased amount of OPT fiber to filtration properties of drilling fluid

From Figure 2, it can be observed as the fluid loss was reduced with increase addition of OPT fiber into drilling mud, the resultant filter cake thickness were increased. As the fluid loss was reduced from 6.5 ml to 5 ml, the cake thickness was increased from 0.5 mm to 0.79 mm. Several researchers have showed similar observation. Okon et al., found that addition of 10g, 15 15g and 20g of rice husk to water based mud increase the cake thickness from 1mm to 1.5mm, 2.4 mm and 3.2 mm respectively [12]. For the same amount of rice husk added, the fluid loss volume reduced from 47 ml to 35 ml, 24.5 ml and 16.5 ml respectively [12]. A study by Ramasamy & Amanullah, found that addition deceased date tree waste fiber from 10 ppb to 30 ppb have reduced the fluid loss for 4 samples from 0 ml, 3 ml, 7ml and 4 ml to 0 ml respectively [10]. For the same condition, the cake thickness were increased from 12.7mm, 14 mm, 13 mm, 12 mm to 29 mm, 21 mm, 19 mm and 21 mm respectively [10].

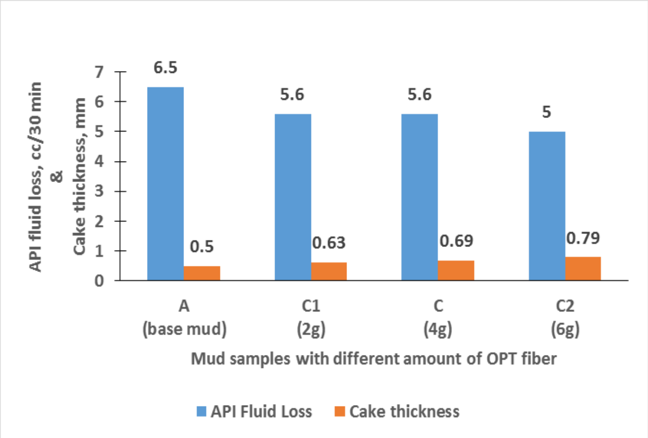

Figure 2: Effect of increase amount of OPT fiber to filter cake thickness

However, the maximum thickness of filter cake was still within the acceptable limit. The cake thickness should be below 1.6 mm to 2 mm [1], [25]. Therefore, if more amount of OPT fiber is added to reduce the fluid loss and as long as the filter cake thickness produced is still within the acceptable limit, OPT fiber still can be used as FLC.

B. The effect of different sizes of OPT fiber to filtration properties.

Figure 3 shows the effect of different sizes of OPT fiber added in drilling mud to fluid loss. It can be observed the use of smaller sizes of OPT fiber into drilling fluid did reduced the fluid loss from 6.5 ml to 5.2 ml. Mud sample B formulated with smallest OPT fiber size (<75 micron) yield the lowest 5.2 ml of fluid loss. Based on the findings, the hypothesis made was the use of smaller size of the fiber will yield the lower fluid loss. This is because smaller particle capable to fill the spaces between the filter cake as compared to the coarser particles during filtration process [7], [8], [11].Therefore, fluid loss was reduced. Similar trends shows by several researchers. Ghazali et al., observed addition of 150 micron, 250 micron and 500 micron of lemongrass to the water base mud resulting the fluid loss of 5 ml, 5.3 ml and 5.5 ml [5]. Majid et al., found that, addition of fine durian rind powder yield in 4.1 ml of fluid loss. While, the addition of coarse durian rind powder resulting around 11 ml of fluid loss [8].

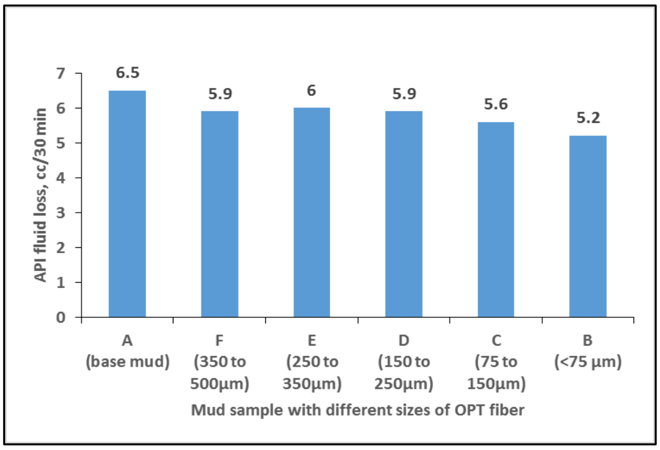

Figure 3: Effect of different sizes of OPT fiber to filtration properties of drilling mud.

Other than that, OPT fiber can act as FLC because it is comprised of cellulose and hemicellulose. Cellulose and hemicellulose could absorb the water in drilling fluid. Therefore, the base fluid can be retained preventing from loss of fluid took places. Cellulose and hemicellulose is hydrophilic and contains large amount of hydroxyl group. Therefore, it is possible that the moisture sorption process can be achieved through hydrogen bond [20]. Cellulose is classified as hygroscopic since it will absorb water and swell [28]. However, as we can observe from Figure 2 and Figure 3, there was only small reduction of fluid loss took places. The addition of OPT fiber of 6g only reduced the fluid loss approximately by 23%. This is maybe due to the presence of lignin in between cellulose and hemicellulose. The presence of lignin in between them cause disturbance for the absorption of water to take place. Lignin itself is hydrophobic therefore it does not absorb water [28]. It also interfere the swelling and refining of the fiber. Lignin will react as encrusting agent for the cellulose and hemicellulose loose matrix and commonly referred as plant cell wall adhesive [29]. Therefore, the surrounding and crosslinking of lignin between the polysaccharides- cellulose and hemicellulose in the cell wall provide an obstacle for effective water/ moisture absorption process to take place.

C. The effect of different sizes of OPT fiber to mud losses and mud invasion.

Sand bed test was conducted with 6% of OPT fiber at different sizes. The purpose is to determine the suitable sizes of OPT fiber that can plug the pore spaces in between of 20/40 sand. From Figure 4, it can be observed that mud sample A, J and K has failed to prevent or reduce the mud losses. Other mud samples that are G, H, and I have successfully reducing mud losses into formation. The mud invasion below 5 cm shows the good performance of LCM [7]. For the sample A, mud losses occur due to base mud contain no bridging particles thus pore space between sand or formation is not plugged. For the samples E and F, failure in preventing or reducing mud losses is due to the size of the OPT fiber is much larger than the pore sizes. Due to larger particle sizes than pore spaces between sand, the fiber is not placed in between the pore spaces. Formation of mechanical bridge did not take places, thus no seal was created to prevent or reduced loss of mud. According to [30], the median particle size of the bridging additive need to be equal to or slightly greater than one-third the median pore size of the formation. Therefore, the expected suitable fiber sizes, which is one-third of 20/40 sand frac range from 100 to 300µm. For the sample G, H and I, the use of suitable size of OPT fiber enable the fiber to travel into the pore spaces. Mechanical bridge was formed and finer particles were able to deposit on top of it. Therefore, low permeability seal was formed. Low permeability seal able to reduce or prevent the further mud loss and mud invasion into formation. Based on the results below, OPT fiber size of 75 to

100µm is the most suitable size since mud sample H has the lowest mud invasion of 1.0 cm.

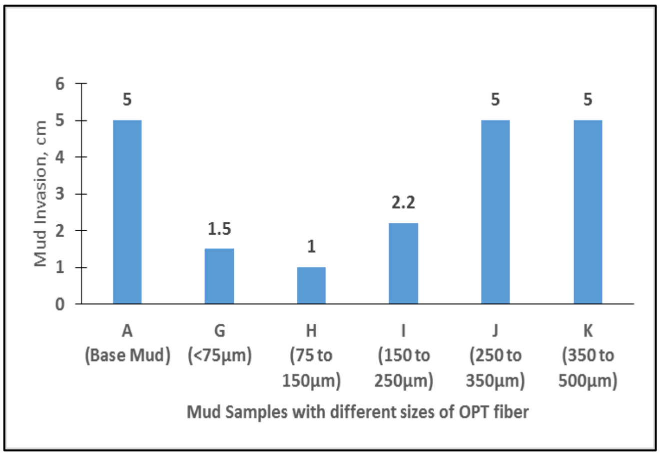

Figure 4: Effect of different OPT fiber sizes to mud invasion

After sand bed test finished, the residual drilling fluid located on top of 20/40 sand bed was removed. From Figure 5, it can be observed only thin deposition of OPT fiber formed on top of sand bed for mud sample H. This shows most of the OPT fiber added to drilling mud have travelled into the pore spaces between sand bed to form bridge and seal. Instead, from Figure 6, a thick deposition of OPT fiber was observed for mud sample K. This is because, the size of OPT fiber used in mud sample K is too large and unsuitable for pore size 20/40 sand bed. Therefore, most of the OPT fiber cannot invade and travelled into the pore spaces thus only deposited on top of the sand bed.

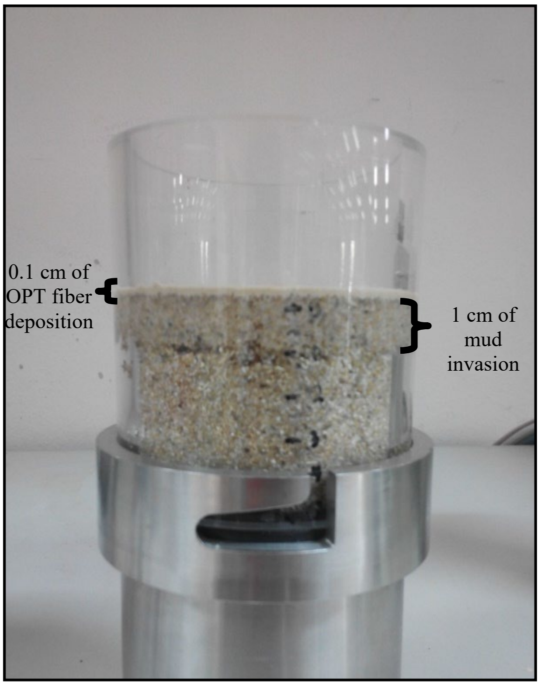

Figure 5: Thin deposition of OPT fiber on top of sand bed for mud sample H

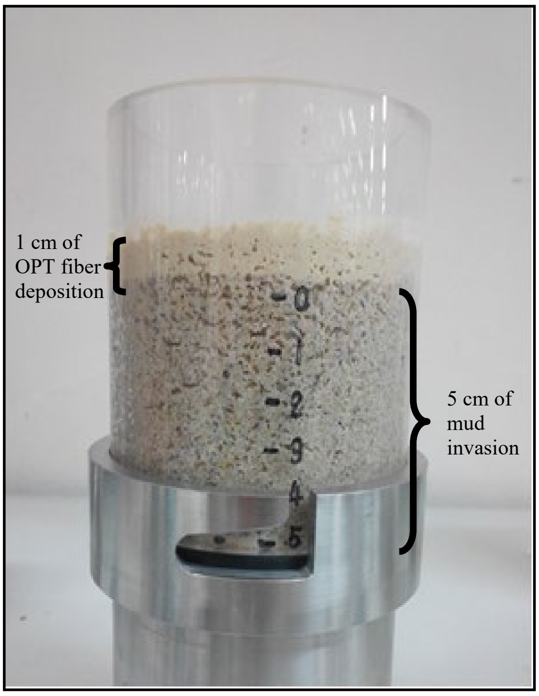

Figure 6: Thick deposition of OPT fiber on top of sand bed for mud sample K

D. The effect of different and increase concentration of OPT fiber to mud losses and mud invasion

According to Abrams, the concentration of the bridging size solids must be at least 5 percent by volume of the solids in the final mud mix [30]. Figure 7 shows the result of the sand bed test experiment conducted at increasing concentration of <75µm OPT fiber. It can be observed that mud sample A and G1 having 5 cm mud invasion instantly. It shows that, at 0% and 2% concentration of OPT fiber used in drilling mud, the LCM performed poorly to prevent mud losses. These results was expected to occur since the concentration of the OPT fiber used in mud samples is less than 5%. Enough high concentration of fiber LCM is needed to create the bridge [14]. Therefore it can be concluded, 0% and 2% concentration of OPT fiber is not enough to form a mechanical bridge thus no low permeability seal was created. On the other hand, it can be observed that mud sample G and G2 having 1.5 cm and 1.1 cm mud invasion respectively. It shows a good performance of LCM in combatting mud loss at 6% and 10% concentration of OPT fiber. Thus it can be concluded for this experiment, 6% concentration of OPT fiber is the minimum concentration needed to form mechanical bridge. Thus, finer particles were deposited on top of bridge and to form a low permeability seal. The result obtained agreed to Abrams' Rule that state the concentration of the bridging size solids must be at least 5% by volume of the solids in the final mud mix [30]. Alsabagh et al., found the use of 6% cellulosic fiber produce the best performance in combatting lost circulation. They observed at 6% of fine peanut hulls added into the water based mud, the spurt loss was reduced from 120 ml to 24 ml [6]. They also stated, the use of 6% that provide the best result is agreed to Abrams' Rule [6].According to [31], mud invasion will increase as the concentration of LCM depleted. They also state that, concentration of LCM should be maintained properly in order to maintain the good seal.

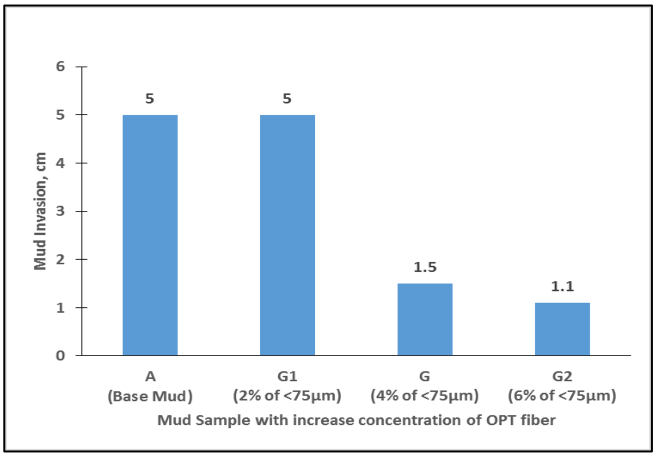

Figure 7: Effect of increase concentration of OPT fiber to mud invasion

From Figure 7, the observation also was made on the effect of increasing concentration of the OPT fiber used in the drilling mud. It can be observed, addition of OPT fiber from 2% to 6% and 10% have reduced the mud invasion from 5 ml to 1.1 ml. A conclusion could be drawn as concentration of OPT fiber used increased, mud losses into formation is reduced. It also shows OPT fiber yield a good performance as LCM concentration increased. Several researchers have observed similar trends. Increase concentration of sized durian rind used from 0 lb/bbl to 20 lb/bbl had reduced the mud losses from 3500 ml to 2600 ml [32]. The increase concentration of fiber used from 10 ppb to 30 ppb had reduced the spurt loss for four samples from 0 ml, 2 ml, 3 m, 2ml to 0 ml [10]. The increasing concentration of associative polymer NIF from 0 ppb to 10 ppb reduced the total mud invasion to 0.5 cm [26].

IV. Conclusion

The conclusion can be drawn from this study is Oil Palm Trunk (OPT) fiber could be used as either FLC or LCM. The lowest fluid loss of 5.2 ml could be observed as the smallest sizes of OPT fiber (<75µm) was added to drilling mud. As OPT fiber was added at increased amount of 2g to 6g into drilling mud, the fluid loss was reduced from 6.5 ml to 5 ml. The thickness of filter cake was increased as higher amount of OPT fiber was added into drilling mud. However, all filter cake thickness is still within appropriate limit. As for the LCM, lowest mud invasion was achieved with mud sample H. It shows, the OPT fiber range from 75 to 150 µm is the most suitable for 20/40 sand bed. The addition of different concentration of OPT fiber shows that at least 6% concentration is needed to reduce mud invasion. The addition of OPT fiber at increasing concentration of 2% to 10% has reduced the mud invasion from 5 cm to 1.1 cm.

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