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The Study of The Sealing Performance of Fibrous-Laden Drilling Fluid Over Simulated Lost Zone Under Overbalanced Pressure Conditions

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ABSTRACT - Numerous studies have examined the sealing capabilities of fibrous-amended drilling fluid by measuring filtrate volumes and assessing how well the fibrous plant fragments close fissures. Limited studies have been conducted on the mechanical strength of these materials during the sealing process and their response to plastering pressure. Therefore, this study addressed this gap by providing new data on the relationship between the mechanical strength of fibres and the operating pressure of drilling muds, specifically in preventing lost circulation. The study was carried out using a new experimental methodology involving a high-precision universal tensile machine, which accurately measured the performance of plant fragments in the sealing varying diameters of simulated fractures. Furthermore, the simulated fractures with sizes commonly observed in the field were created to mimic real lost circulation scenarios. The sealing pressure of each fibrous-laden drilling fluid were also observed. The results showed that drilling muds without fibrous additives failed to prevent continued circulation loss, as it lacks the structural integrity necessary for forming a solid muds cake and inhibits infiltration. In contrast, adding plant fragments to drilling muds enables the formation of robust muds cake structures, effectively mitigating drilling fluid losses.

Keywords: drilling fluid, lost circulation, filtration, fibres, muds cake.

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INTRODUCTION

Rheological properties are important in evaluating the effectiveness of drilling muds. These properties govern the entrance of drilling fluid into boreholes, and their behaviour changes when subjected to dewatering against pressure of the borehole wall [1]. The rheological behaviour of modified drilling fluid may differ due to variations in dewatering properties and the formation of composite bonds that could impact flow characteristics [2]. According to preliminary studies, increased viscosity and enhanced fibres bonding contribute to the reduction of lost circulation in drilling muds, thereby making the use of fibres in drilling operations popular [3][4][5].

Fibres can originate from various sources, but numerous studies have investigated the use of cost-effective plant fibres that are readily available [6]. The potential benefits of incorporating organic fibres to mitigate lost circulation were demonstrated by Taufiket al. [5]. This added synthetic organic fibres to an aged-bentonite suspension and observed that fibres concentrations ranging from 10 to 15 kg/m3 led to mitigation of lost circulation by up to 25 kg/m3 in high lost zone. Their findings showed a slight increase in the plastic viscosity and yield point of fibres-laden fluid compared to drilling muds without fibres inclusions. Moreover, successful trials of fibres implementation have been carried out in several exploration wells.

Hossain et al. [4] conducted a study to quantitatively assess the effects of organic fibres on the rheological behaviour of drilling muds. Hossain et al. focused on grass-based drilling muds and used grass particles of varying sizes, namely 300 μm, 90 μm, and 35 μm. Their findings revealed that the consistency curves of muds followed a Bingham plastic model. Moreover, as the concentration of grass particles increased, plastic viscosity of muds and yield point exhibited an upward trend. Forrest et al. [2] explored using ground peanut hulls as fibres additives in bentonite polymer suspensions. Their investigation showed that including peanut fibres led to an increase in viscosity with higher fibres concentrations. The impact of fibres size was significant, as the viscosity decreased when fibres were separated into smaller sizes ranging from 0.1 to 1.0 mm.

Another study by Alsabagh et al. [7] focused on using coarse and fine-sized bagasse and sawdust particles, ranging from 0.037 mm to 3.35 mm, as additives in drilling muds. The amended drilling muds exhibited shear stress vs. shear rate behaviour that followed a Power law model, showing non-Newtonian fluid characteristics. The consistency index, denoted as n, was less than 1 for the investigated muds, suggesting shear thinning behaviour. This property could be advantageous for effective wellbore cleaning during muds circulation.

These studies collectively highlight the positive impact of organic fibres derived from various sources on the behaviour of drilling muds in terms of mitigating lost circulation and improving rheological properties. However, specific data regarding the influence of Eichhornia crassipes plant fibres on the rheological behaviour of drilling muds is currently lacking.

This study aims to assess the plastering behaviour of fibrous plant fragments when incorporated into drilling muds based on bentonite suspensions.Three categories of ECP fragments, namely, fibres, ground fibres, and ground stalks, were employed as the primary amendments in this investigation.

During the experiments, the concentration of plant fragments was modified while keeping the volumes of water and masses of bentonite constant. The plant fragments were introduced into the clay-based fluid and allowed to age for 16 hours. This initial mixing and aging process with bentonite mixtures provided sufficient time for colloid hydration [1]. Furthermore, Subsequently, the fiber-amended drilling muds experienced filtration behavior by measuring changes in pressure fluctuations while universal tensile machine was used to push the filtration plunger downward with constant shear rate.

The obtained data generated pressure vs. time curves, enabling the quantification of the sealing performance of plant fragments. These results evaluated the effectiveness of plant fragments as amendments to drilling muds in bridging and inhibiting the escape of filtrates from fissures that may occur along the walls of boreholes formed during drilling.

METHODOLOGY

Ground fibers, ground stalks, and dried fibers were mixed at concentration of 0.81% w/w with 22.5 g of bentonite and 350 ml of deionized water. The mixture was thoroughly blended using a high-speed mixer operating at 6000 RPM. Subsequently, the three different mixtures were left to age for 16 hours at an ambient temperature of 21 °C. Before conducting filtration measurements, they were stirred again to ensure consistency and uniformity.

Laboratory Work

The filtration apparatus was made up of a sample container and a plunger with a rubber seal for extruding drilling fluid. At the base of the container, plates with slots were fixed to simulate fractures. The sample container was a cylindrical tube made of polypropylene, measuring 56.8 mm in inside diameter and 127.3 mm in height. To ensure a leak-free testing environment, a rubber-like seal made of thermoplastic elastomer was fitted at the end of the plunger. Furthermore, a thin layer of grease was applied to the seal before testing to reduce friction. The sample container had a capacity of 350 ml of drilling fluid. During the test, which lasted for 1200 seconds, the plunger was pressed down at a controlled displacement rate. This caused drilling fluid to flow through the simulated fissure. The slotted disc used in the apparatus had a diameter of 66.37 mm and a thickness of 15 mm. The slots on the disc were 32.76 mm long and ranged in width from 1 to 5 mm. The disc was equipped with a rubber O-ring to prevent any leakages during filtration process.

Filtration apparatus employed a Zwick All-Round Z005 test frame from Zwick Roell AG in Ulm, Germany, to push down the plunger, simultaneously measuring displacement and applying load. TestExpert®II software was used to record and analyze the collected data on force and displacement. To achieve a crosshead displacement speed of 2 mm/min, twin linear screw jacks were employed, maintaining this speed for 1200 seconds. The compressive force was measured by a 5 kN load cell with an accuracy of 0.05 N. Throughout the experiment, pressure was recorded in response to any detected sealing activities caused by fluid containing plant fragments.

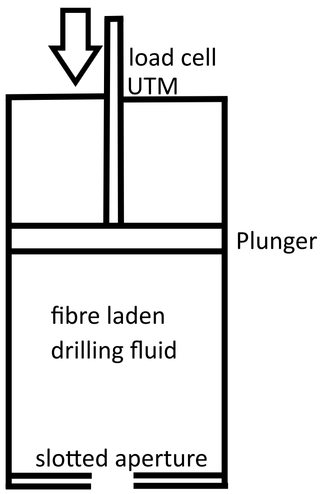

Figure 1
Laboratory setting up experimental apparatus.

(a). Simulated Fissures

(b). Plant fragments

Figure 2
Simulated fissures and plant fragments used in this study

RESULT AND DISCUSSION

The clay bentonite with a water content of 6.0 wt.% showed unhindered flow through all tested slot sizes, indicating the absence of muds cake formation. Consequently, the bentonite suspension effortlessly drained out of filtration barrel without requiring piston assistance. This outcome clearly showed the inability of the system to restrict further fluid losses from the sample container effectively.

Figure 3 shows that fibres-based drilling fluid maintained a consistent stress level regardless of displacement. When dried fibres was applied to a 1 mm slot disc, it reached a peak pressure of 20 kPa after 800 seconds of extrusion time. However, as the squeezing process continued, pressure associated with the sealing capability slightly decreased, reaching 15 kPa during the final period t.

Figure 4 shows the sealing capability of ground fibres, highlighting its inferior ability to seal slotted discs. The only noticeable improvement was observed when incorporating a 1 mm slot disc. During the 1200-second experiment, the sealing fluctuated at a pressure of 15 kPa.

The ground stalk-based fluid showed the highest maximum pressure (approximately 20 kPa) among all treatments for a 1 mm thick slot. The maximum pressure declined with increasing slot diameter, and pressure fluctuations were observed for slotted discs up to 2 mm. In the case of a 3 mm slotted disc, pressure increased as the duration of the experiment progressed, as shown in Figure 5. However, the ground stalks were unable to seal 4- and 5-mm slotted discs effectively. The slot openings were covered by stalk fragments with varying size distributions, while solid particles of drilling fluid filled the spaces between these fragments, impeding further infiltration of drilling fluid.

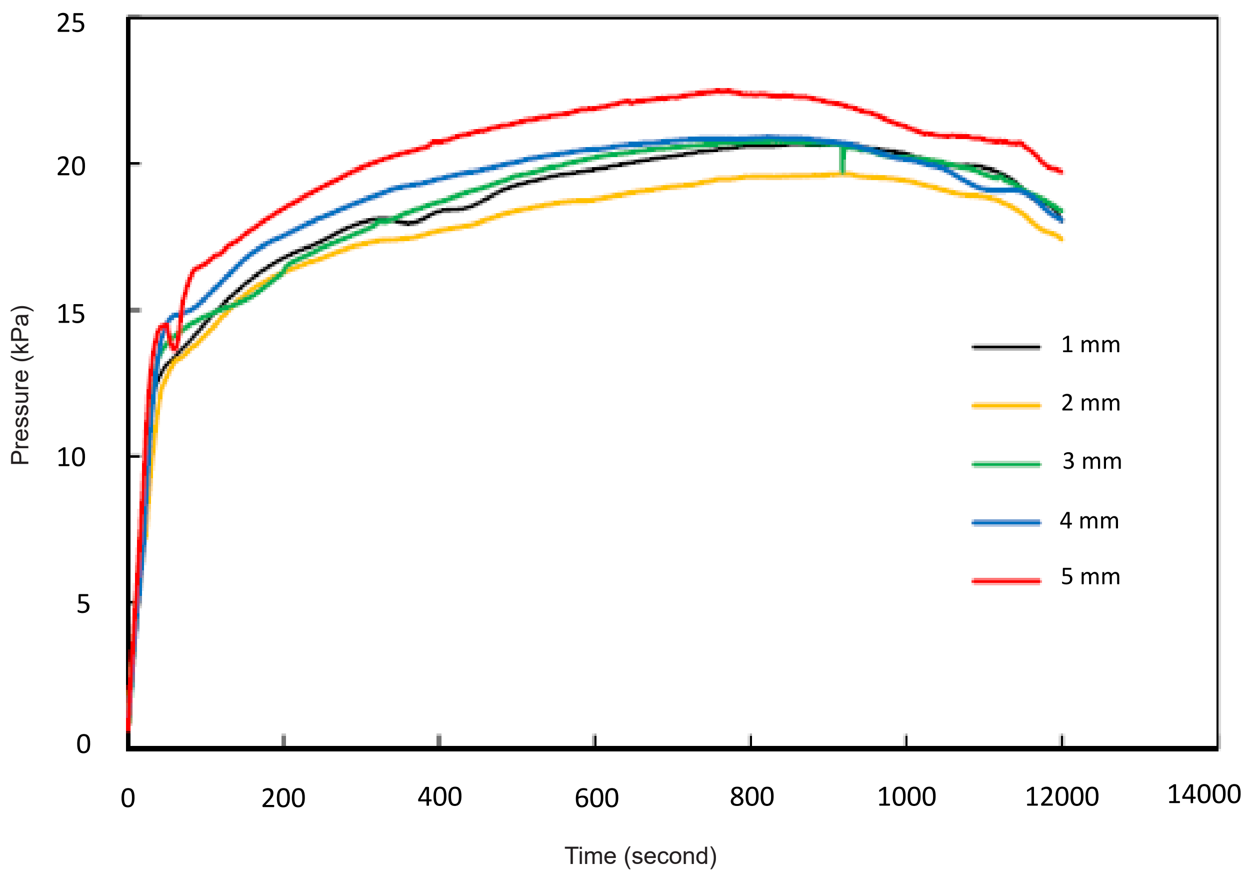

Figure 3
Fibres-laden fluid sealing pressure

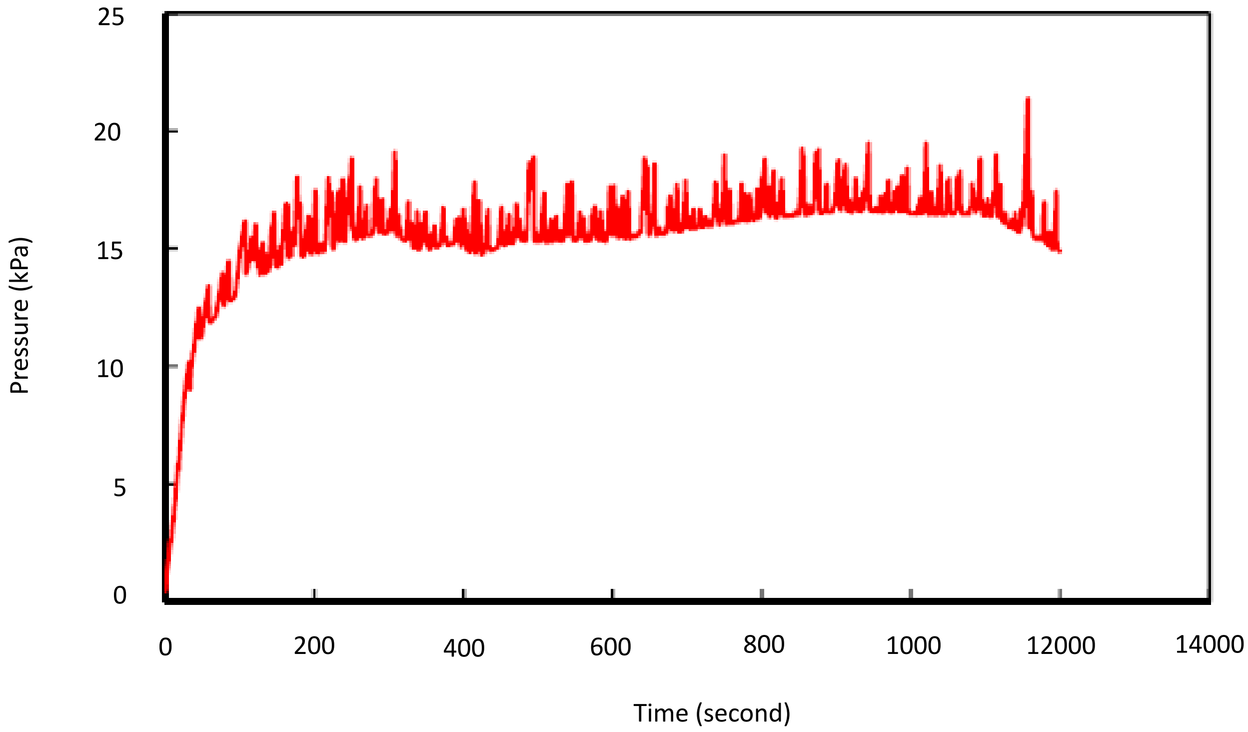

Figure 4
Ground fibres-laden fluid

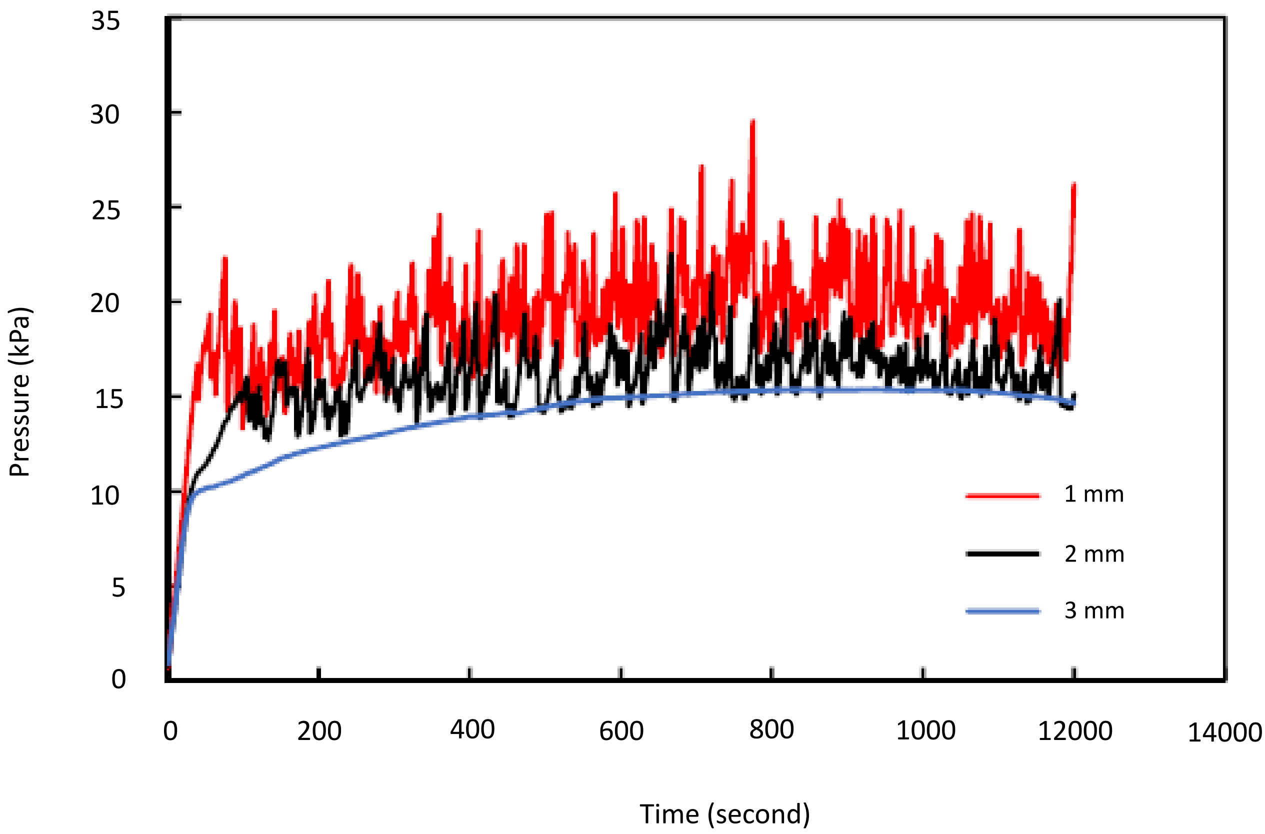

Figure 5
Stalk grind-laden fluid

CONCLUSIONS

In conclusion, static filtration experiments were conducted on fibrous material, with a 6 wt.% bentonite suspension used as the control. Three different ECP fragments, namely, dried fibres, ground fibres, and ground stalk, with a 0.81% concentration, were mixed with water and bentonite for the experiments.

- The 6 wt.% bentonite suspension freely flowed through the slotted disk, showing high susceptibility to lost circulation. It failed to form muds cakes on the slotted disks of any diameter.
- Ground fibres exhibited the poorest sealing ability for slot-shaped fissures among the ECP fragments. Ground fibres were unable to seal any slot thickness on the slotted disks.
- Fibres showed better performance when used to plaster slot apertures. The detected maximum pressure fluctuated between 15 and 20 kPa, regardless of the hole size up to 5 mm.
- Ground stalk outperformed the other fragments in terms of the sealing holes. It effectively reduced losses up to a 3 mm slotted fissure, with the maximum pressure decreasing as the hole diameter increased. Previous rheological data showed no flocculation occurred at any concentration of ground stalk. Additionally, it exhibited shear thinning flow behaviour, which could benefit drilling process.

ACKNOWLEDGEMENT

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GLOSSARY OF TERMS

Symbol	Definition
API	American Petroleum Institute
OBM	Oil based Mud
PEM	Politeknik Energi & Mineral
PV	Plastic Viscosity
YP	Yield Point
AV	Apparent Viscosity

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