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USING DURIAN RIND AS BRIDGING MATERIAL TO OVERCOME FLUID LOSS AND LOST CIRCULATION PROBLEMS IN DRILLING OPERATIONS

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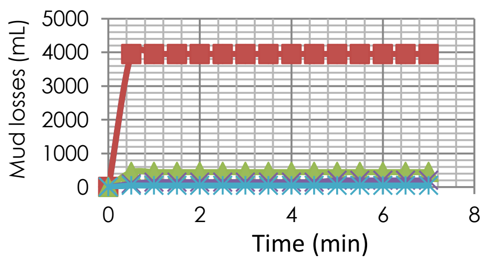
Graphical abstract



Abstract

Lost circulation is one of the drilling operational problems. It refers to the total or partial loss of drilling fluid into highly permeable zones or natural or induced fractures. This problem is likely to occur when the hydrostatic head pressure of drilling fluid in the hole exceeds the formation pressure. Today, managing lost circulation remains a significant challenge to oilwell drilling operations because it may contribute to high non-productive time. It is imperative to note that the overbalance pressure situation also can cause the invasion of mud filtrate into production zones which will result in formation damage. To address these problems, an experimental investigation has been done on durian rind as an alternative fluid loss and lost circulation materials in water-based mud. Durian rind was selected as a mud loss control material because it contains close to 20% pectin which may complement the formation of high quality mat-like bridges across openings of the formation. The test involved the use of standard mud testing equipment and a lost circulation test cell. Durian rind powder was prepared by cleaning and cutting the durian rind into small pieces of 1 to 2 cm, and then dried them in an oven at 60°C for 48 hours before grinding into five different sizes from coarse to ultra-fine while Hydro-plug, the commercial lost circulation material was supplied by Scomi Energy. The fluid loss test was conducted using a standard low pressure filter press while the bridging test was carried out at 100 psi of pressure difference and ambient temperature using a lost circulation cell. Fine durian in the water-based mud gave the best fluid loss control compared to coarse durian rind, fine and coarse Hydro-plug. The experimental results also showed that at 15 lb/bbl (42.8 kg/m^3) optimum concentration, coarse and intermediate durian rind have outperformed Hydro-plug by showing an excellent control of mud losses in 1 and 2 mm simulated fractures.

Keywords: Bridging material, durian rind, Hydro-plug, lost circulation, mud losses

Abstrak

Kehilangan edaran ialah satu daripada masalah operasi penggerudian. Permasalahan ini merujuk kepada seluruh atau sebahagian daripada lumpur gerudi yang hilang ke dalam zon yang berkebolehtelapan tinggi atau retakan semula jadi atau retakan yang berpunca daripada operasi penggerudian. Kehilangan edaran boleh berlaku apabila tekanan turus hidrostatik lumpur gerudi di dalam lubang adalah melebihi tekanan formasi. Pada masa kini, mengurus kehilangan edaran masih merupakan suatu cabaran yang besar kepada operasi penggerudian sebuah telaga minyak kerana masalah terbabit boleh menyumbang kepada masa tak produktif yang tinggi. Suatu perkara penting yang harus dititikberatkan ialah tekanan imbang lebih juga boleh mendorong pencerobohan turasan lumpur ke dalam zon pengeluaran yang akan mengakibatkan berlakunya kerosakan formasi. Bagi menangani masalah terbabit, suatu kajian telah dilaksanakan terhadap kulit durian sebagai bahan pilihan kawalan kehilangan bendalir dan kehilangan edaran dalam lumpur dasar air. Kulit durian dipilih sebagai bahan kawalan kehilangan lumpur kerana mengandungi hampir 20% pektin, yang boleh membantu pembentukan titian yang berkualiti tinggi merentasi bukaan yang terdapat pada formasi. Ujian melibatkan penggunaan kelengkapan pengujian lumpur dan sel penguji kehilangan edaran. Serbuk kulit durian disediakan dengan membersih dan memotong kulit terbabit menjadi kepingan-kepingan kecil yang berukuran 1 sm hingga ke 2 sm. Seterusnya, kepingan-kepingan kecil itu dikeringkan di dalam ketuhar pada suhu 60°C selama 48 jam sebelum dikisar menjadi lima saiz yang berlainan, iaitu daripada kasar kepada sangat halus. Bahan kehilangan edaran komersil Palam Hidro pula dibekalkan oleh *Scomi Energy*. Ujian kehilangan bendalir dilaksana menggunakan penuras tekan piawai bertekanan rendah manakala ujian perapat dilakukan pada tekanan pembezaan 100 psi (690 kPa) dan suhu ambien menggunakan sel kehilangan edaran. Serbuk halus kulit durian di dalam lumpur dasar air menghasilkan kawalan terbaik kehilangan bendalir berbanding serbuk kulit durian kasar, palam Hidro halus dan kasar. Keputusan kajian juga menunjukkan bahawa pada kepekatan optimum 15 paun/tong (42.8 kg/m^3), serbuk kasar dan serbuk sederhana kasar kulit durian telah memberikan prestasi yang lebih baik daripada palam Hidro dengan mempamerkan kawalan kehilangan edaran yang sangat baik bagi retakan terselaku 1 mm dan 2 mm.

Kata kunci: Bahan perapat, kulit durian, palam Hidro, kehilangan edaran, kehilangan lumpur

1.0 INTRODUCTION

Lost circulation is one of the serious drilling operational problems and in fact is often called the number one problem in drilling. It refers to the reduction in the rate of mud returns from a well compared to the rate at which the mud is pumped into the hole during a drilling operation or in extreme condition the entire volume of drilling mud can be lost into the formation [1]. In oil and gas industry, lost circulation is one of the biggest contributors to drilling non-productive time, which costs the industry around US$800 million per year [2]. One of the notable methods to overcome the lost circulation problem is by spotting the lost circulation material (LCM) into the porous or fractured formation which can be natural or artificially induced. But the use of lost circulation materials, which are available in international market in the form of granular, flake, fibrous, or blended, may not be able to seal effectively the fractures in some cases while in other cases may induce formation damage to the porous formation due to plugging of production zones [3,4]. This problem can be remedied using a relatively expensive imported lost circulation material. Therefore, this paper discusses the potential of durian rind, a fibrous and water-wet waste material, as a bridging material to overcome lost circulation problem facing the drilling operations.

The potential of durian rind was also explored in the form of controlling fluid loss which may occur during drilling, cementing, and completion jobs. In drilling a hole, fluid loss to the formation occurs when hydrostatic pressure of the drilling fluid in the hole exceeds the formation pressure. The invasion of mud filtrate and mud solid particles into the porous formation may lead to formation damage [5].

Durian (*Duriozibethinus L.*) — a member in the Bombaceae family — is well-known as the *King of Tropical Fruits* in Southeast Asia especially in Malaysia

[6]. The statistical crop data from the Malaysia Ministry of Agriculture and Agro-Based Industry showed that the production of this fruit in Malaysia in 2013 was about 320 164 metric ton. The production of durian in 2013 was in fact about 20 000 metric ton higher than in 2012. For one durian fruit, 50-65 percent comprises creamy yellow flesh which is consumed as foods while the rest (45 to 55 percent) is described as waste includes seed and skin [6]. According to Manshor *et al.* [7], 1 kg of durian skin waste approximately can generate 400 g of durian rind fiber.

The fibrous nature of durian rind, which contains 18.6% of pectin and 73.5% of cellulose (and further divided into α-cellulose and hemi-cellulose) [6], is able to form a mat-like bridge over porous formation when added to a drilling fluid and pumped into hole. This mat-like bridge phenomenon can reduce the size of the openings of the formation, permitting the colloidal particles in the mud to rapidly deposit a filter cake thus completely sealing the formation that otherwise might require a cement job [4]. Articles in open literature show durian rind has been used in many applications such as biocomposites [7], environment [8], and health [9,10] but it is yet to be exploited as lost circulation or bridging material in water-based mud [11].

2.0 EXPERIMENTAL

The durian rind powder was prepared according to the method suggested in "Sugar Production from Durian (Durio Zibethinus Murray) Peel by Acid Hydrolysis" [12]. The method was initiated by cleaning and cutting the durian rind into small pieces from 1 to 2 cm, and then dried them in an oven at 60°C for 48 hours.

In the following step, dried durian rinds were ground and sieved into five different sizes, namely ultra-fine, fine, medium, intermediate, and coarse size (Table 1). Those sizes of durian rinds were categorised according to American Petroleum Recommended Practice 13C [13].

Table 1 Definition of particle sizes

Particle size (micron)	Particle classification
Greater than 2000 (2 mm)	Coarse size
250 – 2000 (0.25 – 2 mm)	Intermediate size
74 – 249 (0.074 – 0.249 mm)	Medium size
44 – 73 (0.044 – 0.073 mm)	Fine size
2 – 43 (0.002 – 0.043 mm)	Ultra-fine size

The performance of durian rind as lost circulation material in water-based mud was compared with commercial granular lost circulation material, Hydro-plug [14]. The basic water-based mud was prepared based on the formulation suggested by Scomi Energy, as shown in Table 2.

Table 2 Base mud formulation

Additives	Quantity (ppb)
Bentonite	15.0
Caustic soda	0.25
Soda ash	0.25
Starch	1.00

Note: 1 ppb = 2.85 kg/m^3

The mud density was kept constant at 9.8 ppg (1174 kg/m^3) throughout this study. To maintain the weight, barite was added into water-based mud at a desired amount. The API filtration or fluid loss test was carried out to determine its ability as a bridging material in controlling fluid loss and also the optimum concentration of durian rind (to be used in lost circulation experimental work) using a standard filter press. The compositions of durian rind and Hydro-plug (supplied by Scomi Energy) added into water-based mud were 5 lb/bbl (14 kg/m^3 or 1.43% by weight), 10 lb/bbl (25.8 kg/m^3 or 2.86 % by weight), 15 lb/bbl (42.8 kg/m^3 or 4.29% by weight), 20 lb/bbl (57.1 kg/m^3 or 5.71% by weight), and 25 lb/bbl (71 kg/m^3 or 7.14% by weight).

The bridging test was done using a lost circulation test cell at 100 psi differential pressure and ambient temperature of 75°F (24°C). Three different slots of 1 mm, 2 mm, and 3 mm were used in the test cell as simulated fractures. The performance of durian rind and Hydro-plug in their respective water-based mud samples was evaluated at the end of seven minutes testing time where the quantitative evaluation was done according to criteria outlined in Table 3 [11].

Table 3 Quantitative performance evaluation of LCM [11]

Total mud loss (ml)	Indication
< 350	Excellent control
350 – 700	Good control
700 – 1050	Moderate control
1050 – 1400	Fair control
>1400	No control

3.0 RESULTS AND DISCUSSION

The API filtration test was conducted on the coarse and fine durian rind and Hydro-plug in water-based mud for all concentrations, i.e., 5-25 lb/bbl (14 kg/m^3 or 1.43% by weight - 71 kg/m^3 or 7.14% by weight) as suggested by Scomi Energy. The results show that water-based mud with durian rind produced lower fluid loss compared to water-based mud with Hydro-plug. For instance, fine durian depicts the best fluid loss control, i.e., 4.1 ml at the end of 30 minutes (lower than the field recommended fluid loss of 8 ml for 30 minutes) as shown in Figures 1 to 4 than water-based mud with fine Hydro-plug, coarse Hydro-plug, and coarse durian rind. The findings show that fine durian is able to fill up the pores in the mud cake formed on the filter paper, and eventually it swells, forms the required bridge, and prevents further fluid loss.

The experimental results also show that 15 lb/bbl (42.8 kg/m^3 or 4.29% by weight) was the optimum concentration for both lost circulation materials, as shown in Figures 1 to 4. It gave the lowest fluid loss compared with 5-10 lb/bbl (14 kg/m^3 or 1.43% by weight - 25.8 kg/m^3 or 2.86% by weight) and 20-25 lb/bbl (57.1 kg/m^3 or 5.71% by weight - 71 kg/m^3 or 7.14% by weight) of concentrations. This shows that 15 lb/bbl (42.8 kg/m^3 or 4.29% by weight) of durian rind and Hydro-plug could form a strong mat-like bridge than other concentrations. For 5-10 lb/bbl (14 kg/m^3 or 1.43% by weight - 25.8 kg/m^3 or 2.86% by weight), both mud samples had insufficient bridging particles to form a strong mat-like bridge while 25 lb/bbl (71 kg/m^3 or 7.14% by weight) of durian rind and Hydro-plug gave a comparable performance as 15 lb/bbl (42.8 kg/m^3 or 4.29% by weight). This means that any concentrations higher than 15 lb/bbl would not produce any significant effect on the test. On the contrary, it would not be the case as depicted in Figure 3. The concentration above or at 25 lb/bbl (71 kg/m^3 or 7.14% by weight) would likely to produce significant effect for fine durian rind.

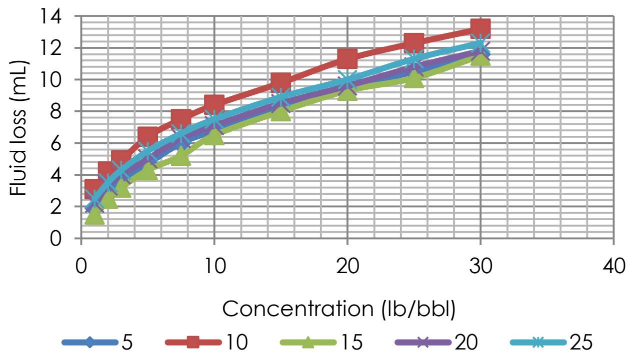


Figure 1 Fluid loss for fine Hydro-plug in water-based mud at different concentrations

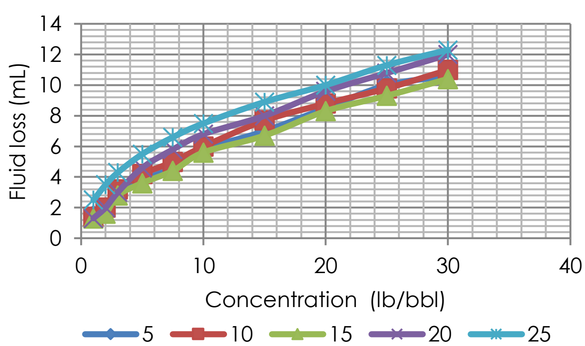


Figure 2 Fluid loss for coarse Hydro-plug in water-based mud at different concentrations

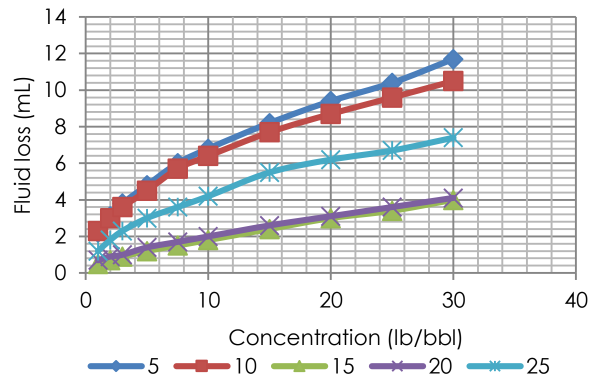


Figure 3 Fluid loss for fine durian rind in water-based mud at different concentrations

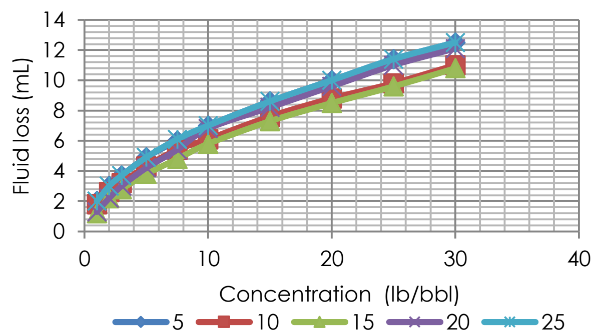


Figure 4 Fluid loss for coarse durian in water-based mud at different concentrations

The bridging test showed that coarse and intermediate size durian rind powders could excellently control mud losses in 1 mm fracture while medium size durian rind recorded a mere good control status. But fine and ultra-fine sizes durian rind failed to control mud losses in 1 mm fracture (Figure 5). For 2 mm simulated fracture, coarse size durian rind showed an excellent control of mud losses (Figure 6). On the other hand, other sizes of durian rind failed to control mud losses in the said fracture. Figure 7 shows that durian rind of all sizes failed to control mud losses in 3 mm fracture. The results show that coarse durian rind has suitable size particles to form a good mat-like bridge which could reduce the openings of 1 mm and 2 mm simulated fractures. This is followed by rapid deposition of colloidal particles, which were formed by pectin in the durian rind, in the mud on the mat-like bridge and consequently would seal the fractures. The much smaller durian rind particles failed to give any impact because they were too small, even though with the presence of pectin, to form a mat-like bridge and eventually would be driven into the pores of formation and might lead to formation plugging.

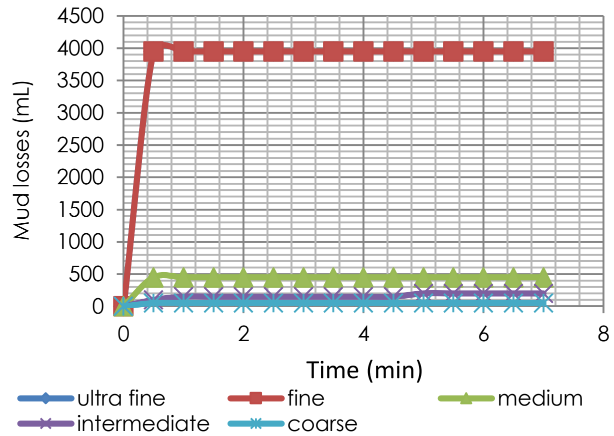


Figure 5 Total mud loss of 15 lb/bbl (42.8 kg/m³) durian rind of different sizes in water-based mud at ΔP = 100 psi (690 kPa), T = 75°F (24°C), and 1 mm simulated fracture

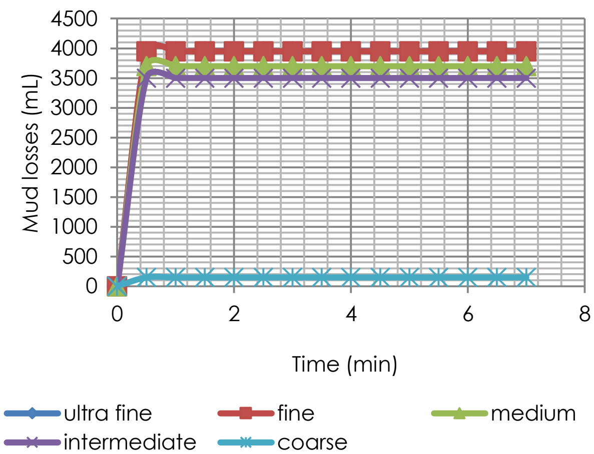


Figure 6 Total mud loss of 15 lb/bbl (42.8 kg/m³) durian rind of different sizes in water-based mud at ΔP = 100 psi (690 kPa), T = 75°F (24°C), and 2 mm simulated fracture

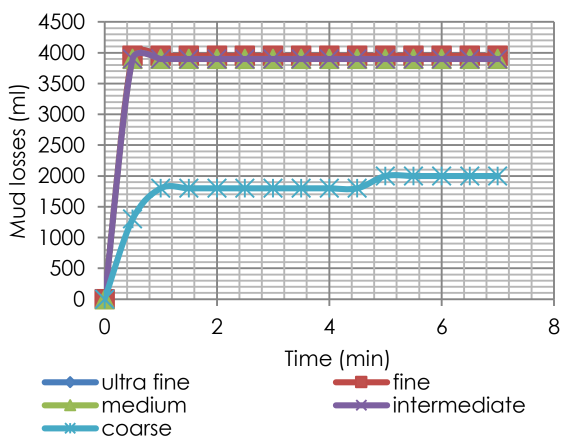


Figure 7 Total mud loss of 15 lb/bbl (42.8 kg/m³) durian rind of different sizes in water-based mud at ΔP = 100 psi (690 kPa), T = 75°F (24°C), and 3 mm simulated fracture

Figure 8 shows that coarse size Hydro-plug could control fairly mud losses in 1 mm simulated fracture as compared to other sizes which failed to produce the required performance. Figures 9 and 10 show that Hydro-plug of all sizes failed to control mud losses in both 2 and 3 mm simulated fractures. This shows that the granular Hydro plug failed to form a good mat-like bridge as compared to durian rind.

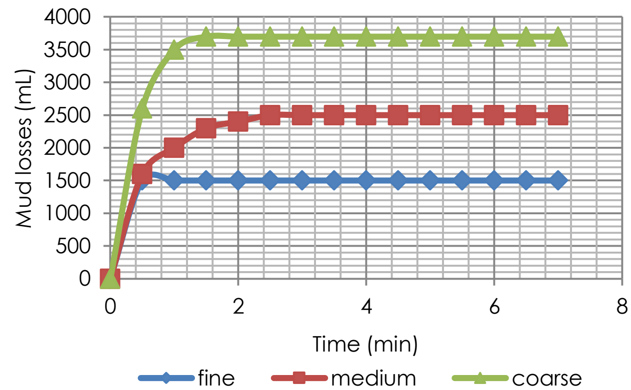


Figure 8 Total mud loss of 15 lb/bbl (42.8 kg/m³) Hydro-plug of different sizes in water-based mud at ΔP = 100 psi (690 kPa), T = 75°F (24°C), and 1 mm simulated fracture

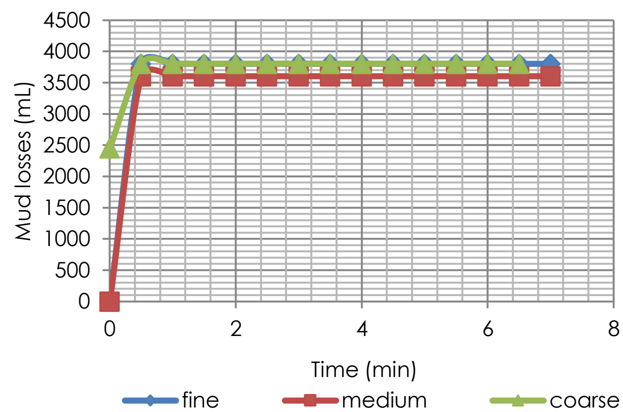


Figure 9 Total mud loss of 15 lb/bbl (42.8 kg/m³) Hydro-plug of different sizes in water-based mud at □P = 100 psi (690 kPa), T = 75°F (24°C), and 2 mm simulated fracture

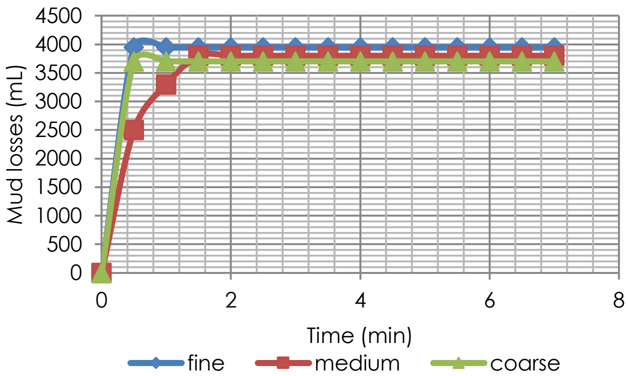


Figure 10 Total mud loss of 15 lb/bbl (42.8 kg/m^3) Hydro plug of different sizes in water-based mud at ΔP = 100 psi (690 kPa), T = 75°F (24°C), and 3 mm simulated fracture

Generally, the results achieved were in good agreement with the statement made by Abrams [15] who said that lost circulation materials should have an appropriate particles sizing for the fracture openings to be sealed. The medium and coarse durian rind particles which were measured from 0.25 mm to slightly greater than 2 mm satisfied his suggestion saying that the particle size of bridging materials should be equal to or slightly greater than one-third the pore size of the formation. The durian rind was found to have outperformed the Hydro-plug — confirmed the findings of Ismail and co-workers [16] — due to higher friction between the fibrous materials [17]. Coupled with the presence of pectin (pectin is highly hydrophilic in nature and itself is completely soluble in water), it has a tendency to hydrate very rapidly, forming clumps [18]), and subsequently allows durian rind powders to maintain the integrity of the formed seal within the fractures.

4.0 CONCLUSIONS

The following conclusions have been framed out accordingly:

(1) Durian rind has the potential to be used as fluid loss and lost circulation materials in water-based mud due to the presence of pectin and higher friction between the fibrous materials.
(2) Water-based mud with fine durian rind produced lower fluid loss, i.e., 4.1 ml at the end of 30 minutes, compared to coarse durian rind and Hydro-plug, and fine Hydro-plug.
(3) At 100 psi (690 kPa) of pressure difference and ambient temperature, 15 lb/bbl (14 kg/m^3) of intermediate and coarse durian rind particles have shown excellent control of mud losses in 1 and 2 mm simulated fractures but failed to combat total mud losses in 3 mm fracture.
(4) Coarse Hydro-plug could fairly control total mud losses in 1 mm but failed in both 2 mm and 3 mm simulated fractures.
(5) Fine Hydro-plug and durian rind failed to control total mud losses in all sizes of simulated fractures.

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