iJET EXPLORE International Journal of Engineering & Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-3444

International Journal of Engineering and Technology Volume 4 No. 3, March, 2014

The Use of Crassostrea Virginica as Lost Circulation Material in Water-Based Drilling Mud

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ABSTRACT

Lost circulation of drilling fluid results in higher operational expenses which makes it imperative to design the fluid, such that minimal invasion of the fluid occurs in the formation. To achieve this, Lost Circulation Materials (LCM) are required which is expected to seal the fractures hence, the performance of Oyster Sea-shells (Crassostrea Virginica) as a lost circulation material is being investigated knowing that it is rich in Calcium Carbonate.

Sea shells were prepared, pulverized and sieved to obtain fine grain particles which were analyzed in the laboratory for various properties. A fractured zone lost circulation test procedure was employed using a medium-sized fracture at 1000 psi. pressure drop and temperature of 808ºF. The tests were performed in triplicates and the rheological and gel strength results were obtained. It was seen that although the Oyster Sea shell is not a viscosifier, it passes API acceptability test for API acceptable range of Plastic Viscosity and Yield Point. The plastic viscosity and Yield point of the mud were compared to that of the VG Gel and the trend observed was a good indication that the Oyster Sea shell would support Wyoming bentonite. Locally sourced Oyster Sea-shell can be used as a lost circulation material as its fine-sized grades performed excellently in controlling mud loss for the water-based mud in the laboratory. The 2:1 blend of Oyster Sea-shell outperformed the 2:1 blend of coarse and medium ground walnut shells in some of the water-based drilling mud tested; hence, the Oyster sea shell is a suitable substitute for conventional LCMs.

Keywords: *Drilling Fluid, Formation Pressure, Lost Circulation Material, Oyster Sea-shells Water-based Mud*

1. INTRODUCTION

Lost circulation is defined as an undesirable loss of drilling fluids into the fractures and the voids of the formation during drilling or cementing; these problems in drilling are not confined to any single area. They may occur at any depth where the total pressure exerted against the formation exceeds the formation breakdown pressure. Loss Circulation is the loss of whole drilling fluid or mud at any depth from the hydrostatic fluid column to the formation. (Bourgoyne *et al.,*1991). Lost circulation is both troublesome and costly to the drilling company. Drilling fluids are usually lost to natural or induced formation fractures. These fluids may also be lost through highly permeable formations (Kim and Wampler, 2009).

During the drilling of wells, fractures which are created or widened by drilling fluid pressure are suspected of being a frequent cause of lost circulation; it could also happen in cement slurries during cementing operation. These losses may vary from a gradual lowering of the mud level in the pits to a complete loss of returns. (Howard and Scott, 1951). The loss of drilling mud or cement slurry results in increased drilling time, loss of expensive mud, plugging of productive formations, and/or loss of well control. Even with the best drilling practices, circulation losses can occur. Lost circulation severity is often categorized as seepage, partial, sever and total lost circulation; seepage loss (when the severity of the loss is 1 to 10 bbl/hr), partial loss (when the severity of the loss is 10 to 500 bbl/hr) and complete loss (when the severity of the loss is greater than or equal to 500 bbl/hr). (Pilehvari and Venkata, 2002). Lost circulation is a frequent problem during drilling and occurs when the formation fracture resistance is exceeded by the pressure in the wellbore, i.e. when the hydrostatic pressure is greater than the formation pressure. The mud loss may occur in any formation and in every depth with a wide range of severity depending on the loss zone. Mud losses happen in formations with high permeability, natural or induced vertical and horizontal fractures and also in case of the cavernous and vugular rocks. Small natural fractures are found in virtually any formation, however, some natural fractures found in limestones and chalks may result in very high mud losses (Howard and Scott, 1951). As far as the induced fractures are concerned, they result from the tensile failure of the formation in the vicinity of the wellbore and could occur in any formation where the pressure in the well exceeds the fracture pressure of the formation. Caverns and vugs are also very problematic type of loss zones which in most cases occur in limestones and dolomites.

Carbon-based materials known as deformable graphite are used to prevent loss of circulation in porous and fractured formations and may be used in any drilling fluid. When added to a drilling fluid they become tightly compressed into porous formations and fractures. They will then expand and contract with the formation without being dislodged. As these types of materials are more expensive they may be supplemented with Calcium carbonate (Chevron Phillip, 2005).

An oyster sea shell, also known simply as a shell, is a hard, protective outer layer possessed by sea creatures that live in the sea. Oyster Sea-shell composed majorly of calcium carbonate ($CaCO_3$) and is found abundantly in many parts of Nigeria at virtually every sea-shore in their thousands. Many are hand-picked by tourists for ornamental purposes. Quite a number of deserted beaches have these oyster sea shells in their millions not being used and just lying fallow. This Oyster seashell, also known as a sea shell is the common name for a hard, protective outer layer, or in some cases a "test", that was created by a sea creature or a marine organism. The shell is part of the body of a marine animal. In most cases this shell is an exoskeleton, usually that of an animal without a backbone, an invertebrate. Seashells are most often found washed up empty on beaches or another part of the coastline after the soft parts of the animal have either been eaten by another animal that attacked it (predation), human beings as sea food or after the animal has died and the soft parts have been eaten by scavengers or have simply rotted out.

Physical Properties of Lost Circulation Materials

Rogers, 1953 and Scott and Lummus 1955 have indicated that granular materials are the most effective type lost circulation materials as determined by the maximum size of the slot or fracture which can be sealed. However, variations in the maximum size fracture which can be sealed by different granular materials graded in identical particle size ranges suggested that certain physical properties must be required of a material for optimum fracture sealing characteristics.
When drilling through thick incompetent formations in areas where high drilling mud weights are required to control high pressure zones, the problem of' lost circulation to recurring induced fractures is common. The normal solution to this problem is to add conventional lost circulation materials to the mud and by-pass the shale shaker so that the materials may be retained in the mud. (Pilehvari and Nyshadham, 2002).

The problem of lost circulation may be addressed through preventive and corrective measures. One important way to prevent lost circulation is managing the wellbore stresses and pre-treating the drilling fluid with selected particulates before entering the depleted formation. The well construction plan should not only address pretreatment and borehole stress treatments, but lost circulation mitigation if it occurs. In this situation both particulate and chemical sealant systems could be used; also subsequent treatments in the form of sweeps, instead of adding into the active drilling fluid system in the suction pit is advised.

(Goins, (1952) defined a seepage loss as the loss of a whole mud less than 25 bbl/hr for water based drilling fluids. This rate of loss may be caused by a number of factors resulting from the drilling operation or it may only be a perceived loss. (Nayberg, 1987) discovered while drilling 50 feet per hour in an 8.5” hole, that 3.5 bbls of whole drilling fluid per hour will be required to fill the new hole drilled.
In their review of recent advances in drilling-mud control, Preston and Chaney, 1942 describe the Gulf Coast of Texas and Louisiana as having thick beds of sand in the Miocene which has been found by experience to take mud under moderate pressures. Consequently, it is advisable to set a protective string of casing through the Miocene sand beds whenever it is necessary to use a mud weighing more than 13 ppg in drilling deeper formations.

Previous experimental work and field experience have shown that the whole mud cannot be forced into a rock formation without fracturing it. However, it has been established that the maximum allowable drilling-fluid loss is in the order of 1 bbl/hr [0.16 m 3 /h], as measured in the mud pits at the surface. Therefore, remedial measures must be taken when the mud loss exceeds this to prevent the resultant effect of stuck pipe and severe formation damage (Suyan et al., 2007). Lost circulation can take place while drilling is in progress or during "trips," when there is pressure imbalance. (Bargci *et al.,* 2000).

Causes of Lost Circulation Zones

There are several situations that can result in lost circulation:

- Formations that are inherently fractured, cavernous, or have high permeability.
- Improper drilling conditions.
- Induced fractures caused by excessive downhiller pressures and setting intermediate casing too high.

Prevention of Lost Circulation

It is not possible to completely prevent lost circulation, because some formations, that are inherently fractured, cavernous, or highly permeable, are not avoidable if the target zone is to be reached. However, minimizing circulation loss is possible if certain precautionary measures are taken, such as:

- Maintaining proper mud weight.
- Minimizing annular-friction pressure losses during drilling and tripping in.
- Adequate hole cleaning.
- Avoiding restrictions in the annular space.
- Setting casing to protect upper weaker formations within a transition zone
- Updating formation pore pressure and fracture gradients for better accuracy with log and drilling data

If lost-circulation zones are anticipated, preventive measures should be taken by treating the mud with Loss Circulation Materials (LCMs) and preventive tests such as the leakoff test and formation integrity test should be performed to limit the possibility of loss circulation.

2. MATERIALS AND METHODOLOGY

Materials and Equipment

Lost Circulation Test Cell, Pulverizer, sieve, spatula, digital weighing machine, rotary viscometer, graduated cylinder, multi-rate mixer, filter paper .mud balance, bentonite, distilled water, Oyster Sea shell (OSS). Mica (fine and coarse), cottonseed hulls, ground walnut shells (fine, medium, and coarse), a blend of fibres, flakes, and granules (fine, medium, and coarse), 2:1 blend of coarse and medium ground walnut shells.

Methodology

The sea shells used for this research were collected from the shores of Oniru beach, bar beach and the Elegushi beach, in Lagos state. The shells were washed to removed dirt or other foreign bodies and subsequently dried. The shells were taken to the geology Laboratory University of Ibadan and crushed with a pulverizer. The Oyster Sea were crushed into fine powder using a pulverizer and sieved, the finest particles were gotten by sieving the crushed sea shells The shells were finally analyzed in the Petroleum Engineering Laboratory University of Ibadan and also at the IESL (International Energy Services Limited) laboratory in Lagos.

The Oyster Sea shells were crushed into fine powder using a pulverizer and sieved to obtain the finest particles possible.

Four different samples (A, B, C, and D) were prepared as shown in Table 1.

Table 1: Mud Preparation

Samples	Composition
A	21g Bentonite + 350 ml distilled water+ 0.0g OSS
B	21g Bentonite + 350 ml distilled water+ 3.0g OSS
C	21g Bentonite + 350 ml distilled water+ 6.0g OSS
D	21g Bentonite + 350 ml distilled water+ 9.0g OSS

The plastic viscosity was calculated using;

Plastic viscosity, $\mu p = \theta 600 - \theta 300$
Yield point = $\theta 300 - \mu p$

LCM sample Preparation

A ratio of 2:1 blend of fine and medium grained Oyster Sea-shell, (10 to 100 mesh), 2:1 blend of Ground walnut shells (30 to 120 mesh) blend of fibres and flakes (80 to 70 mesh). A fractured zone lost circulation test procedure was used, thus a medium sized fracture at Δp =1000 psi, T=808ºF was considered. The LCM weight in all tests ranged from 5 lb/gal to 25 lb/gal. The tests were performed in triplicates.

For the purpose of quantitative performance evaluation of the use of LCM's in drilling mud, the following criteria as shown in the Table 2, are used for total mud loss over 10 minutes of testing time:

Table 2: Criteria used for total mud loss over 10 minutes of testing time

Total Mud Loss Volume (cm^3)	Type of control indicator
0 to 350	excellent
350 to 700	Good
700 to 1,050	Moderate
1,050 to 1,400	Fair
1,400 to 1,750	None

3. RESULTS AND DISCUSSION

Table 3: Rheological and Gel Strength Result of the OSS

Sample	θ600	θ300	Gel 10 mins / 10 Secs	Plastic viscosity(cp)	Yield strength (lbs/100ft^2)
A	25.0	19.0	14/ 10	6.0	13.0
B	30.0	23.0	16/14	7.0	16.0
C	34.0	28.0	20/16	6.0	22.0
D	40.0	35.0	20/18	5.0	10.0

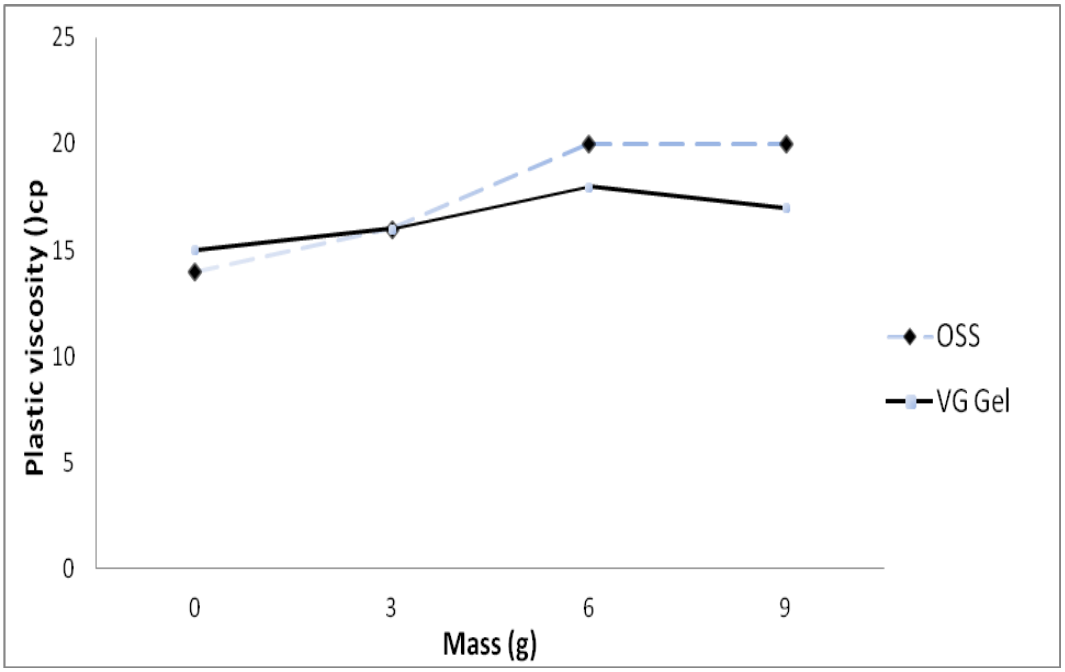

Figure 1: Plastic Viscosity (cp) vs. Mass (g) of OSS and standard VG Gel

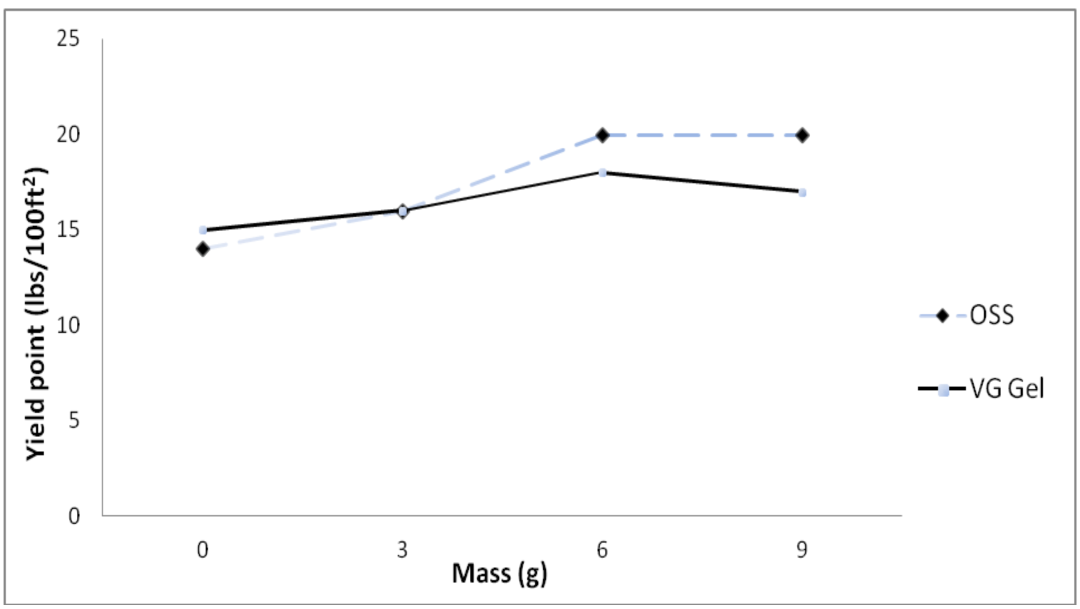

Figure 2: Yield point (lbs/100ft^2) vs. Mass (g) of OSS and standard VG Gel

Figure 1 and **Figure 2** present the Plastic Viscosity and Yield point readings against Mass respectively for a water based drilling fluid for both the Oyster Sea Shell (OSS) and the standard VG Gel used in the Laboratory.

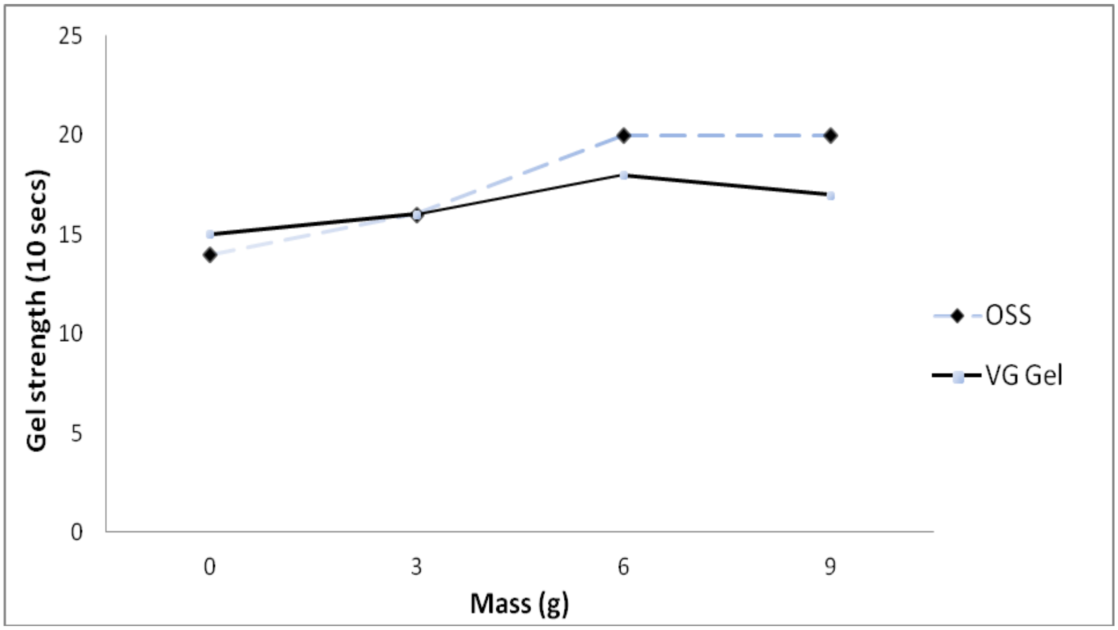

Figure 3: Gel Strength (10 secs) vs. Mass of OSS and standard VG Gel

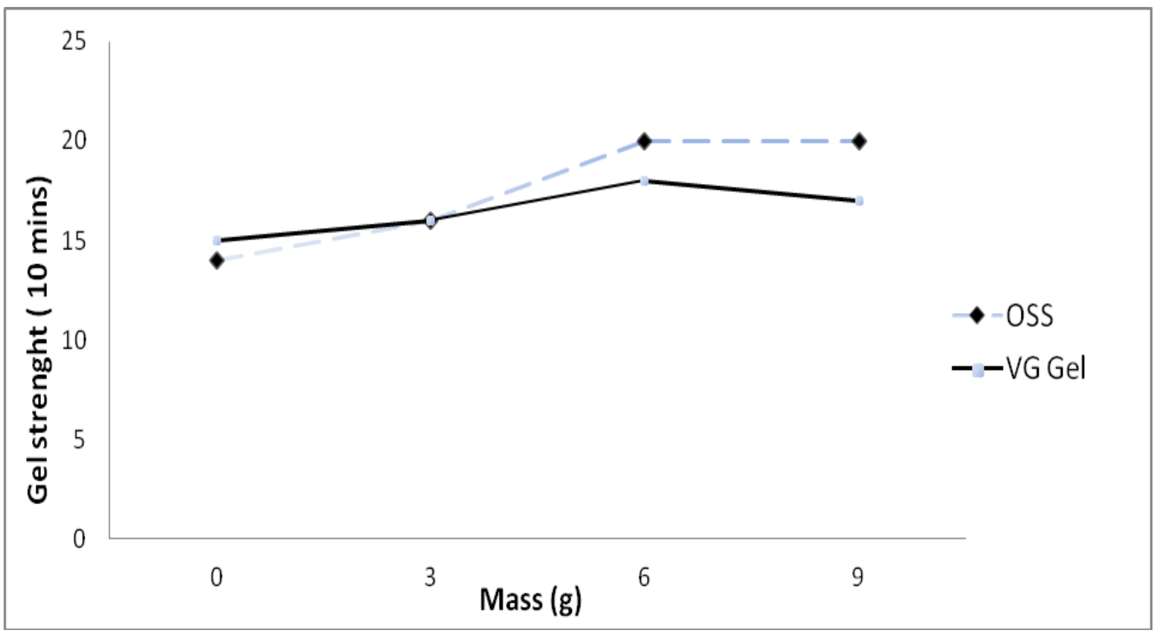

Figure 4: Gel Strength (10 mins) vs. Mass

Lost Circulation Material Results

The Lost Circulation Material results are shown in the following plots of the Oyster Sea Shell (OSS) and the standard VG Gel used in the Laboratory.

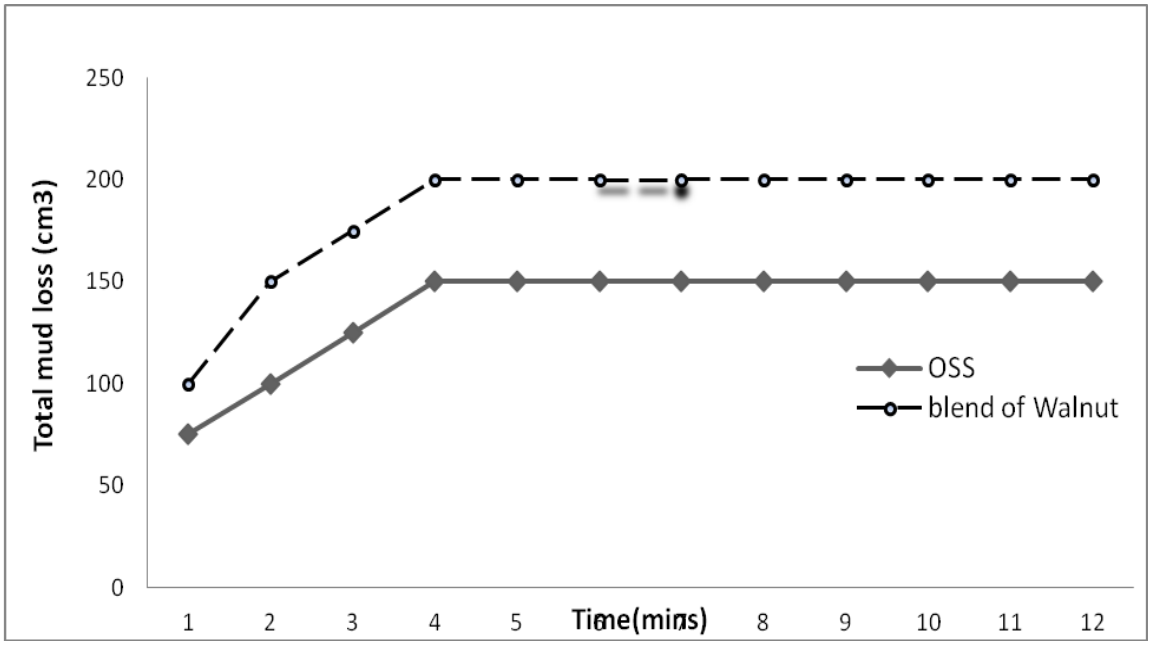

Fig 5: Lost Circulation Test (9.7 lbm/bbl mud + 5 lb/bbl (blended mud)

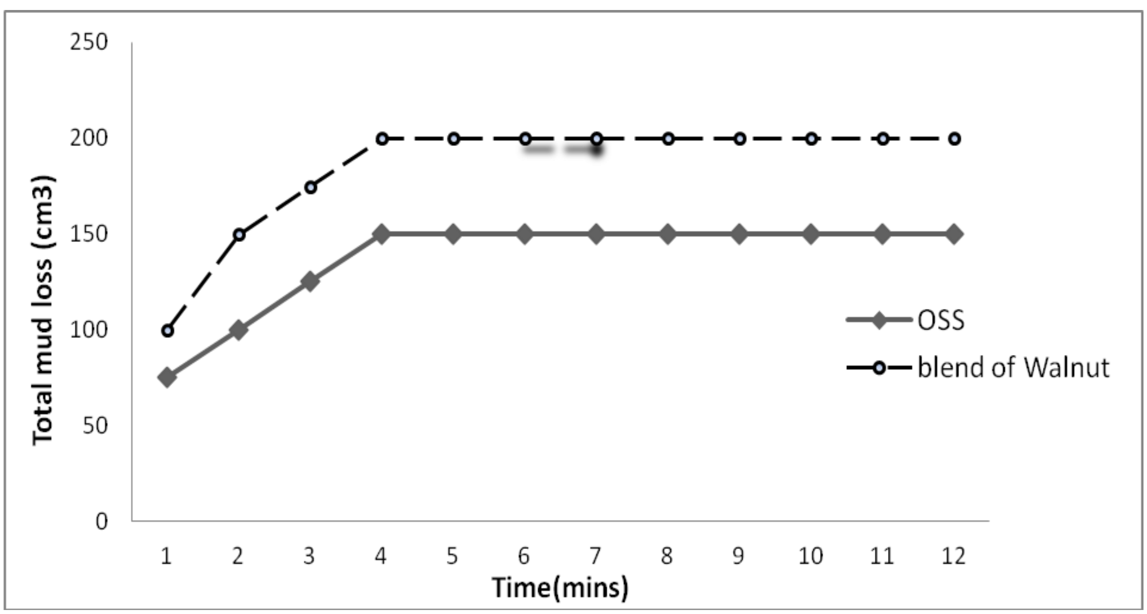

Fig 6: Lost Circulation Test (9.7 lbm/bbl mud + 10 lb/bbl (blended mud)

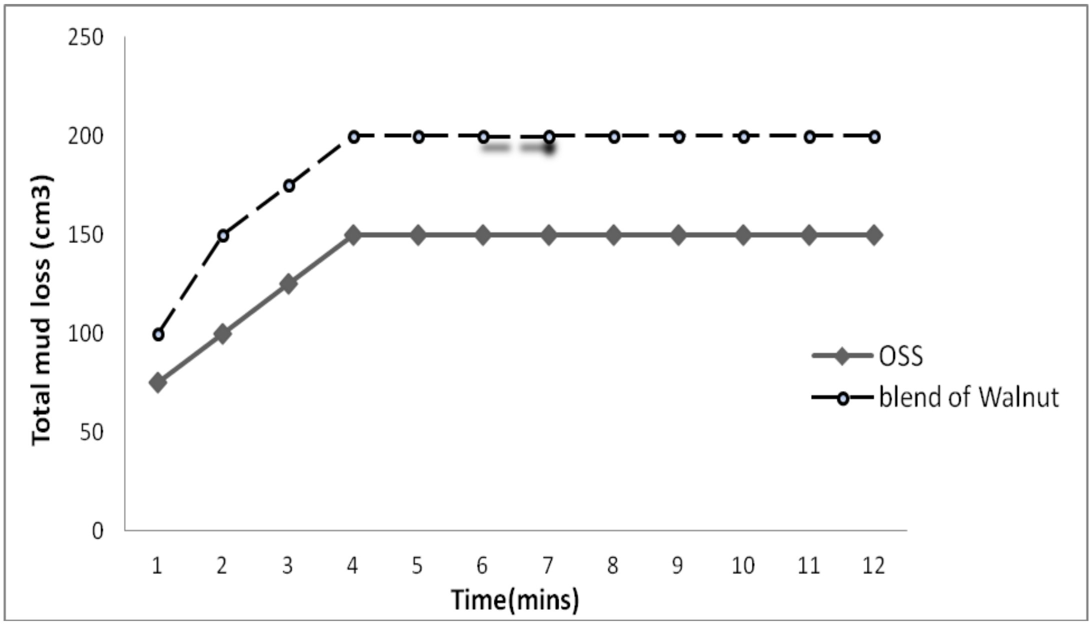

Fig 7: Lost Circulation Test (9.7 lbm/bbl mud + 15 lb/bbl (blended mud)

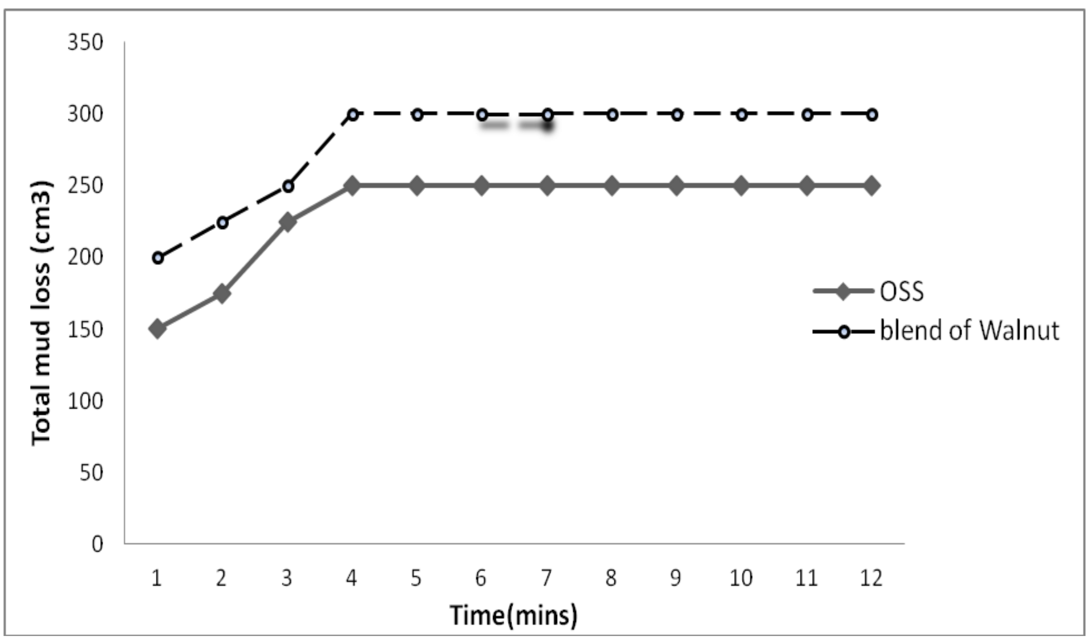

Fig 8: Lost Circulation Test (9.7 lbm/bbl mud + 20 lb/bbl (blended mud)

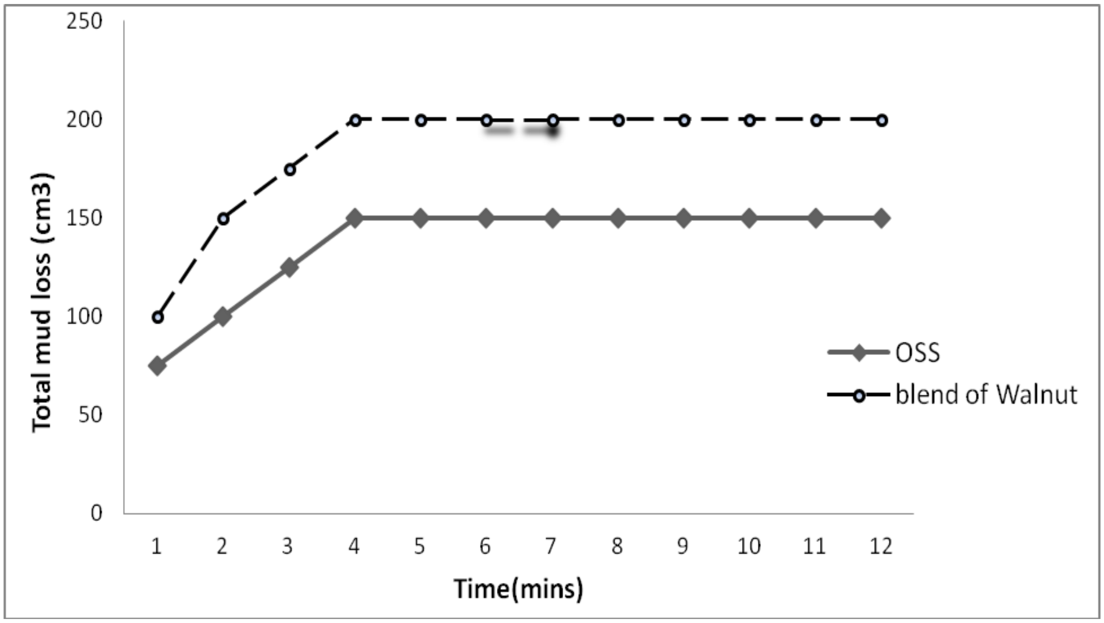

Figure 9: Lost Circulation Test (9.7 lbm/bbl mud + 25 lb/bbl (blended mud)

4. RESULTS

Figs. 5 – 9 present the lost circulation test results for the medium and fine grained Oyster Sea Shell vs. 2:1 blend of ground walnut shell in simulated medium-size fractured formations in water-based drilling muds. The blend of fibres, flakes failed in all tested samples so it wasn't included

5. DISCUSSION

Fig. 1 and Fig. 2 show clearly that although the Oyster Sea shell is not a viscosifier, yet it passes (API) American Petroleum Institute acceptability test for API acceptable range of Plastic Viscosity and also for Yield Point. The plastic viscosity and Yield point of the mud were compared to that of the VG Gel and the trend observed was a good indication that the Wyoming bentonite would support the Oyster Sea shell.

Fig. 3 and Fig. 4 shows us a good match that the Oyster Sea shell passed the Gel strength API acceptability test when compared with the Laboratory prepared VG Gel which invariably shows that the Wyoming bentonite supports the Oyster Sea-shell.
Fig. 5 - 9 shows that the 2:1 blend of the Oyster Sea-Shell performed excellently in controlling mud loss in the 9.7-lbm/gal water-based mud at various LCM concentrations when compared to the tested conventional LCM's at the same concentration i.e.2:1 blend of ground walnut shells (fine, medium, and coarse grades) and a blend of fibres, flakes, and granules (fine, medium, and coarse grades). The fibre flakes and granules in particular failed in all tested cases.

It is known that for a granular LCM to function, the material should have a size appropriate for the fracture opening to be plugged. Oyster Sea-shells possess this property for the slot used in this study. It was found that correct sizing alone is not sufficient in some water-based drilling mud, particularly those with low solids content.

6. CONCLUSION

The fine sized grades of the Oyster Sea-shells performed excellently in controlling mud loss for the water-based mud in laboratory-simulated medium-size fractures when compared to Conventional LCM's-e.g. ground walnut shells (fine, medium, and coarse), and a blend of fibres, flakes, and granules (fine, medium, and coarse) for the same mud's at equal conditions
The 2:1 blend of the Oyster Sea-shell outperformed the 2:1 blend of coarse and medium ground walnut shells in some of the water-based drilling mud tested except for the 9.7 lbm/bbl mud + 10 lb/bbl blend. Therefore, the Oyster sea shell is a suitable substitute for conventional Lost Circulation Material.

7. RECOMMENDATION

The oyster sea shell through this series of test has proven to be a good lost circulation Material and thus more research should be done on it in view to substituting it for the expensive Loss circulation material imported. An avenue should be provided for boosting the harvesting of the oyster sea-shell. One way is eating the oyster and carefully collecting the waste shell at a central depot to be used as Lost Circulation Material.

NOMENCLATURE

API = American Petroleum Institute
OSS = Oyster Sea Shell
LCM = Lost Circulation Materials

IESL = International Energy Services Limited
PV = Plastic Viscosity
YP = Yield Point

Acknowledgement

The Authors wish to thank the staff of the University of Ibadan, Petroleum Engineering Laboratory and the workers of International Energy Services Limited and Dharmattan Nigeria Limited for their support in the course of this project.

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