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Electrical Stability Trend of Invert Oil Based Mud Pre-Mix Formulated with Synthetic Oil and Palm Kernel Oil Blends

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ABSTRACT

This work is aimed at determining the Electrical Stability (ES) of various oil-based mud (OBM) pre-mix formulated with 100% synthetic base oil (SBO), 100% crude palm kernel oil (CPKO), 100% refined palm kernel oil (RPKO), blends of SBO & CKPO, and finally blends of SBO & RPKO. An oil-based mud pre-mix is a preliminary mud, prepared in the blending plant or factory, without the addition of weighting materials, such as barite and some other additives. The OBM pre-mix is conveyed to the rig or drilling site where weighting material and other additives are incorporated and blended prior to being used for the drilling operation. The electrical stability test, usually carried out at a temperature of 49°C, is a very key test for determining whether an OBM pre-mix is good or not. The higher the ES, the better the OBM pre-mix. Thus, the ES tests were carried out on the various OBM pre-mix and the results showed that the OBM pre-mix formulated with SBO & CPKO blends had relatively higher ES values than those formulated with SBO & RPKO blends. Also worthy of note, is the fact that the OBM pre-mix formulated with 40% SBO & 60% CPKO blend gave the highest ES reading of 954 volts. A possible reason why the CPKO blends has better ES values than the RPKO blends is the presence of high saturation of fatty acid, whereas the RPKO has the fatty acids removed in the process of refining. The study therefore implies that the 40% SBO & 60% CPKO blend could be a possible substitute for the conventional 100% SBO in the preparation or formulation of an environmentally friendly OBM pre-mix.

1. Introduction

Oilwell drilling, from the mid-1800s to 1929, has evolved from the dry hole cable tool percussion drilling, where clean water was used to sweep the cuttings out of the wellbore into the hydraulic rotary drilling, where specially formulated drilling fluids are used for transporting cuttings to the surface, filtered off and the fluid recirculated (Caenn, 2018). Until the mid-1800s to late 1920s, the fluid used was just dirt and water. Improvements in the muds used then occurred by using barite for weight control and bentonite for hole cleaning and suspension (Caenn, 2018).

In other to solve many other drilling issues other than weight control, hole cleaning and suspension, Research and Development

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efforts were made by the operators and the service companies in coming up with specialty drilling fluids, which could solve issues, such as viscosity control, wall building and fluid loss control. Thus, a number of independent mud companies, some fairly large, were established during this period, resulting in the developments of specialty or proprietary drilling fluids (Caenn, 2018). Consequently, mud technology, testing, products and systems improved dramatically. Drilling fluids also referred to as drilling mud in cases where the fluid contains water, oil or both were now being provided as specialty products by the mud companies. There are also, drilling fluids, in which the fluid is an array of gases, or liquids other than water. Thus, all drilling muds are drilling fluids, but not all drilling fluids are drilling mud. The drilling mud can take the following forms; synthetic oil-based mud, oil-based mud, water-based mud. Drilling fluids can be used to clean well bore, take out drill cuttings from wells, hold cuttings in suspension, contain formation pressure, minimize friction between the drill string and sides of the well, maintain the stability of the well bore, provide sufficient formation evaluation, cool and lubricate the drilling tools. A drilling fluid is formulated to achieve certain rheological properties such as: Electrical stability, Plastic Viscosity, Gel strength, Filtrate, Mud density. Yield point etc. The successful drilling of an oil and gas well depends to a large extent on the properties of the drilling fluids used during the drilling operation. Therefore, the selection of an appropriate fluid and the maintenance of the essential properties during drilling generally influence the rate of drilling and ensure a successful drilling operation. There are three critical factors that guide the decision on the selection of an appropriate fluid for a drilling operation, namely; cost, technical performance, and environmental impact.

Drilling fluid consists of liquids and solids. The solid content of the drilling fluid is needed to properly control the mud properties such as rheology, density and filter cake building properties. The water-based muds are prepared using either fresh water, seawater, naturally occurring brines, or prepared brines. However, oil-based muds are prepared, using petroleum refined products such as diesel or mineral oil as their major component, while synthetic oil-based muds are prepared using synthetic oils, such as linear alpha olefins (LAO) and isomerized olefins (IO), made to have desired property specifications than traditional petroleum-based oils. In general, water-based muds are good for the less demanding, drilling of conventional vertical wells at medium depths, whereas oil-based muds are much better for greater depths or in directional or horizontal drilling, which places greater stress on the drilling equipment. Synthetic-based muds were developed in response to environmental concerns over oil-based muds, though all drilling muds are highly regulated in their composition, and in some cases specific combinations are banned from use in certain environments (Encyclopedia Britannica, 2017).

In a bid to address environmental concern and reduce cost, the idea of incorporating a biodegradable vegetable oil into the drilling fluid formulation is being considered by researchers. Vegetable oils are known to be potential environmentally friendly drilling fluid component but have not received much attention because of high instability issues (Dosunmu *et al.*, 2010). A sustainable environmentally friendly vegetable oil should be stable during usage under different operating conditions (Alves *et al*., 2008). Malaysian palm oil and palm kernel oil, for instance, have received worldwide approval for preparation of environmentally friendly drilling fluids (Salleh *et al*., 2005). The original Petro-free synthetic base fluid (SBF) system consisted of a mixture of five homologous fatty acid esters (which are the primary constituents of the Malaysian palm oil and palm kernel oil), of which the main component was 2-ethylhexyldodecanoate, but later developed Petro-free formulations containing other SBF such as Linear Alpha Olefins or Poly Alpha Olefins (Neff *et al*., 2000) for stability issues. Thus, this paper is looking at the possibilities of cutting cost, local content value addition, and reducing environmental concern through the use of a biodegradable vegetable oil alone or blending it with synthetic oil, in formulating OBM pre-mix. Hence, the study of the trend in the Electrical Stability of oil-based drilling fluid prepared with Nigeria's CPKO, RPKO and blends of each with SBO. One of the oleochemical products that can be obtained from CPKO are fatty acids esters. CPKO has a fatty acid saturation level of 81% with the largest content being lauric acid (Basiron and Weng, 2004). These fatty acids are widely used in various industries such as tire industry, cosmetics, plastics, paints, pharmaceuticals, detergents, and soaps. In addition, fatty acids are used as raw materials for the production of oleochemicals such as fatty alcohols, fatty amines and fatty esters (Shahidi, 2005).

Electrical Stability (ES) of oil-based muds (OBM) or synthetic oil-based mud (SOBM) or their pre-mix is a measure of the emulsion stability and its oil wetting capacity. The Electrical Stability is determined by applying a steadily increasing sinusoidal alternating voltage across a pair of parallel flat plate electrodes submerged in the oil base drilling fluid. The Maximum Voltage that the mud will sustain across the gap before conducting current is displayed as the Electrical Stability, in unit of volts (Ingenieur, 2018). The composition of the oil-based or synthetic oil-based drilling fluids determines the outcome of the Electrical Stability test. Several conditions influence the Electrical Stability of a given drilling fluid such as resistivity of the continuous phase, conductivity of the non-continuous phase, properties of suspended solids, temperature, droplet size, type of emulsifier used, dielectric properties of the fluid and shear history of the sample (Ingenieur, 2018).

The Synthetic oil-based drilling mud has a generic composition in terms of basic components but with variations in the percentage composition of the components, and in the order of adding the components when preparing the drilling fluid.

Synthetic oil-based mud is composed of the following:

(i) Oil: Low toxicity linear olefins and paraffin, which are often referred to as synthetics.

(ii) Water: The ratio of the oil percentage to the water percentage in the liquid phase of an oil-based system is called its oil/water ratio. Oil-based systems generally function well with an oil/water ratio in the range from 65/35 to 95/5, but the most commonly observed range is from 70/30 to 90/10 (Anon., 2015).

(iii) Primary and secondary emulsifiers: These are for emulsification of the oil and water and contribute to fluid viscosity.

(iv) Brine: Most conventional oil-based mud (OBM) systems are formulated with calcium chloride brine, which appears to offer the best inhibition properties for most shales formations (Anon., 2015). The high salinity water phase helps to prevent shales from hydrating, swelling, and sloughing into the wellbore.

(v) Lime: Usually incorporated to maintain an elevated pH, resist adverse effects of hydrogen sulfide (H_2S) and carbon dioxide (CO_2) gases, and enhance emulsion stability (Anon., 2015).

(vi) Soltex: Organophilic lignitic, asphaltic and polymeric materials are added to help control HP/HT (High pressure/High temperature) fluid loss.

(vii) Bentonite: A specially treated organophilic material, which serves as the primary viscosifier

(viii) Barite: A weighting material which is used to increase system density.

(ix) Wetting Agents and Oil mud thinners: The surfactants used for oil wetting, which can also serve as thinners. Oil wetting is important for ensuring that particulate materials remain in suspension.

In most cases, the synthetic oil-based mud pre-mix, comprising of items (i) to (vii), is prepared and tested to have the desired properties, ES especially. It is then taken to the rig site, where Barite, Wetting Agents and other materials are added and mixed in the mud pit prior to being used for the drilling operations.

2. Materials and Methods

2.1 Materials

The materials used are, 2.5L of Synthetic Base Oil, an Electrical Stability Meter, 1.5L of Crude Palm kernel Oil, 1.5L of Refined Palm Kernel Oil, 3L of Distilled Water, Bentonite, 500g of Organophilic Clay, 500g of Soltex, 500g of Calcium Chloride, 500g of Calcium Oxide (Lime), 1L of Primary Emulsifier, 1L of Secondary Emulsifier, Digital Thermometer, Heater (or hot plate), Mud Mixer, Stop Watch, Weighing Balance and a 10ml Graduated Cylinder.

2.2 Methods

2.2.1 Preparation of SOBM pre-mix

There are variations, from one mud company to another, in the percentage composition of the components, the order of adding the components, as well as the mixing time while preparing the SOBM pre-mix. The order of mixing used in this research is based on a typical composition of oil-based mud used offshore in the UK, with other components, added in small quantities to deal with specific conditions (Offshore Technology Report, 1999). The mixing procedure, with some variations in quantities of some of the materials in OTO 1999, is for the laboratory preparation of 350ml of drilling mud pre-mix as outlined below:

Measure 218.75ml of Synthetic Oil and pour into a mud cup, place the mud cup in the mud mixer and turn in on to start mixing. Weigh 4g of Organophilic clay, added slowly to the synthetic oil in mud cup, and allow stirring in for 5mins, before adding the next components. Weigh 4g of Bentonite and add slowly to the content of the mud cup. Measure 6ml of Primary Emulsifier and add to the content of the mud cup. Measure 2ml of Secondary Emulsifier and add to the content of the mud cup. Weigh 6g of Lime and add to the content of the mud cup. Add brine that was prepared by dissolving 21.75g of Calcium Chloride in 87.5ml of Distilled water, to the content of the mud cup; allow 5mins of stirring before adding the next component. Finally, weigh 4g of Soltex and add to the content of the mud cup and stir for 30mins. Put off the mud mixer and remove the mud cup, the SOBM pre-mix is ready for ES test and any other parameters as may be required. The SOBM pre-mix so formulated has an oil/water (OWR) ratio of 70/30 and a mud weight in the range of 9.1 – 9.2 ppg.

2.2.2 Electrical stability test

Ensure that the ES meter is properly calibrated before use. Place the mud cup on a hot plate and heat the mud pre-mix to a temperature of 49^0C. Remove the cup from the heater, and immediately insert the ES Probe into the mud pre-mix, pressed the start button of the ES-meter, the voltage will raise to a peak value and remain constant. Record that value as the first ES reading. Stir the mud pre-mix again and repeat the test to obtain the second ES reading and repeat the process for the third ES reading. The average of the three ES readings is then recorded as the ES value of the SOBM pre-mix at 49^0C.

The above ES test procedure was carried out, using 100% synthetic base oil (SBO), 100% crude palm kernel oil (CPKO), 100% refined palm kernel oil (RPKO), blends of SBO & CKPO, and finally blends of SBO & RPKO.

Thus, the Synthetic Oil and Crude Palm Kernel Oil (CPKO) blends are as shown below;

i. 100%(218.75ml) Synthetic Oil
ii. 90%(196.86ml) Synthetic Oil + 10%(21.86ml) CPKO
iii. 80%(175ml) Synthetic Oil + 20%(43.75ml) CPKO
iv. 70%(153.13ml) Synthetic Oil + 30%(65.63ml) CPKO
v. 60%(131.25ml) Synthetic Oil + 40%(87.5ml) CPKO
vi. 50%(109.38ml) Synthetic Oil + 50%(109.38ml) CPKO
vii. 40%(87.5ml) Synthetic Oil + 60%(131.25ml) CPKO
viii. 30%(65.63ml) Synthetic Oil + 70%(153.13ml) CPKO
ix. 20%(43.75ml) Synthetic Oil + 80%(175ml) CPKO
x. 10%(21.86ml) Synthetic Oil + 90%(196.86ml) CPKO
xi. 100%(218.75ml) CPKO

Similarly, the Synthetic Oil and Refined Palm Kernel Oil (RPKO) blends are as shown below;

i. 100%(218.75ml) Synthetic Oil
ii. 90%(196.86ml) Synthetic Oil + 10%(21.86ml) RPKO
iii. 80%(175ml) Synthetic Oil + 20%(43.75ml) RPKO
iv. 70%(153.13ml) Synthetic Oil + 30%(65.63ml) RPKO
v. 60%(131.25ml) Synthetic Oil + 40%(87.5ml) RPKO
vi. 50%(109.38ml) Synthetic Oil + 50%(109.38ml) RPKO
vii. 40%(87.5ml) Synthetic Oil + 60%(131.25ml) RPKO
viii. 30%(65.63ml) Synthetic Oil + 70%(153.13ml) RPKO

ix. 20%(43.75ml) Synthetic Oil + 80%(175ml) RPKO

x. 10%(21.86ml) Synthetic Oil + 90%(196.86ml) RPKO

xi. 100%(218.75ml) RPKO

3. Results and Discussion

The results of the ES tests carried out on SOBM pre-mix formulated with 100% synthetic base oil (SBO), 100% crude palm kernel oil (CPKO), 100% refined palm kernel oil (RPKO), blends of SBO & CKPO, and blends of SBO & RPKO are shown below in Fig.s 1, 2 and 3 below.

The plot of ES versus % CPKO and ES versus % RPKO are shown in Fig. 1 and 2 respectively.

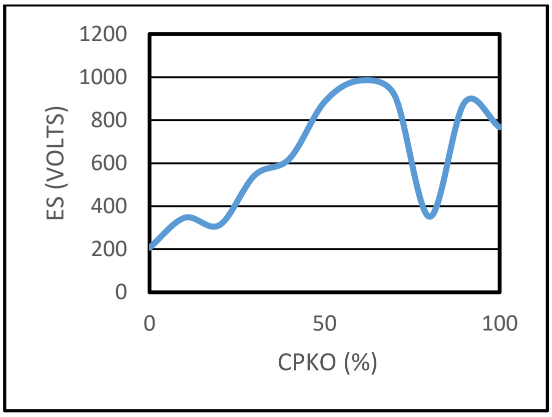

Figure 1: Plot of ES (volts) versus CPKO (%)

From the plot of ES (volts) versus CPKO (%) in Fig. 1 above, the ES reading increases with increase in the %CPKO in the oil blend, from 200 volts at 0% CPKO (i.e. 100% SBO) to 954 volts at 60%CPKO before drastically dropping to as low as 350 volts at 80%CPKO, then rising again to about 900 volts at 90%CPKO, and finally dropping to about 760 volts at 100%CPKO (i.e. 0%SBO).

From the plot of ES versus %CPKO above, it could be said that SOBM pre-mix formulated using 40%SBO/60%CPKO blend, resulted in a relatively high ES of 954 volts, as compared with the SOBM pre-mix formulated with 100%SBO and 100%CPKO, which had ES of 200 volts and 760 volts respectively.

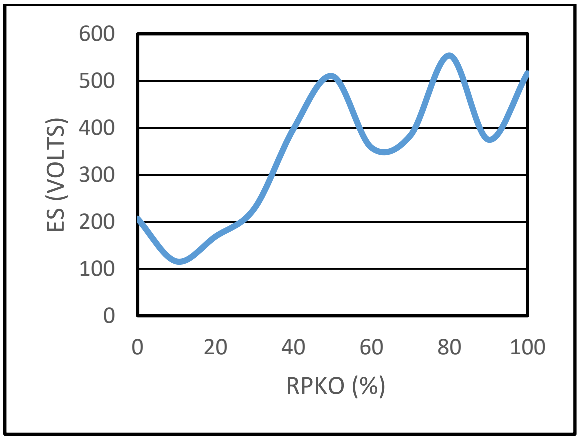

Figure 2: Plot of ES (volts) versus RPKO (%)

From the plot of ES (volts) versus RPKO (%) in Fig. 2 above, the ES reading initially dropped from 200 volts for the 100%SBO to about 120 volts for the 90%SBO/10%RPKO. Thereafter, there was a proportional increase in ES with increase in %RPKO in the oil blend, from 120 volts for the 10%RPKO to 510 volts at 50%RPKO. The variation between ES and %RPKO was no longer proportional between 50%RPKO and 100%RPKO. However, a peak ES value of 550 volts was attained at 80%RPKO.

From the plot in Fig. 2, of ES versus %RPKO, it could be said that SOBM pre-mix formulated using 20%SBO/80%RPKO blend, resulted in a relatively high ES of 550 volts as compared with the SOBM pre-mix formulated with 100%SBO and 100%RPKO, which had ES of 200 volts and 510 volts respectively.

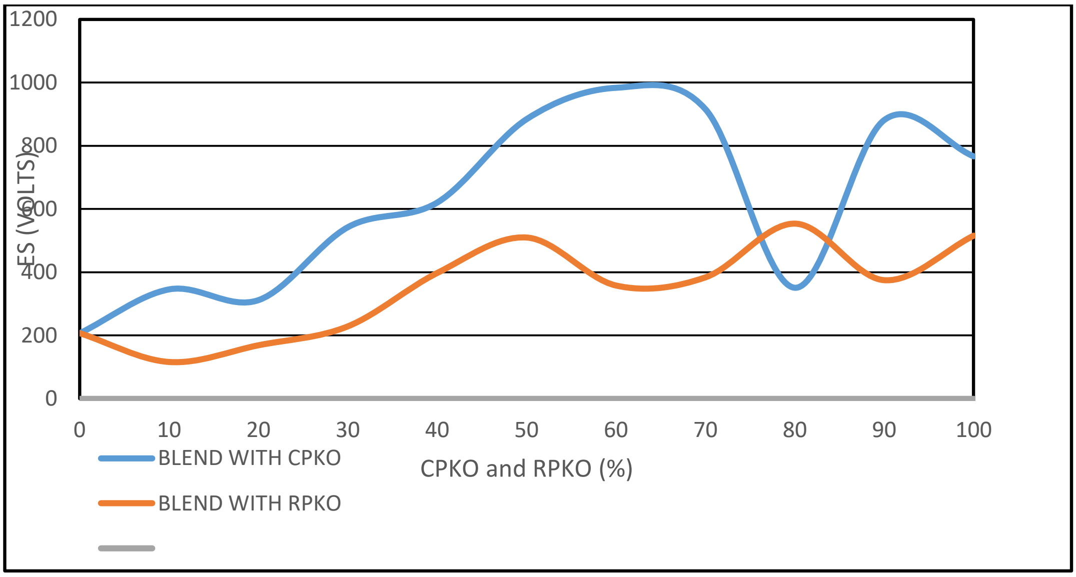

Figure 3: Plot of ES (volts) versus blends of CPKO and RPKO with synthetic oil

From the plot of ES (volts) versus CPKO (%) and RPKO (%) in Fig. 3 above, it could be observed that the blends of CPKO & SBO have have higher ES values than the blends of RPKO & SBO. The only exception is where the ES of RPKO&SBO blends turned out to be higher than the ES of CPKO&SBO blends within the range of 76% to 84% for both CPKO and RPKO.

Conclusion

This study shows that an appreciable increase in the ES value of OBM pre-mix can be achieved through the use of a blend of CPKO and SBO instead of SBO only. This may be as a result of the high percentage composition of fatty acids in the CPKO, which has been reduced drastically in the RPKO in the process of refining. The estimated Electrical Stability for SOBM of mud weight 9 – 10 ppg and OWR 65/35 -75/25 is 200-300 volts (Lyons, 1996), whereas the SOBM pre-mix formulated using 40%SBO/60%CPKO blend resulted in an ES reading of 954 volts; which is quite high. Apart from the ES, there is need to compare the rheological and filtration properties of the SOBM pre-mix formulated with 100%SBO, 100%CPKO and 40%SBO/60%CPKO blend. That way a well-informed decision can be made as to incorporate CKPO in the SOBM formulation as a local content value addition, and in so doing, the cost of the drilling mud will be reduced.

References

[1] Alves, S. and Oliveira, J.D., (2008) “Vegetable based cutting fluid–an environmental alternative to grinding process”, 15th CIRP International Conference on Life Cycle Engineering Pp 1–5.

[2] Basiron, Y. and Weng, C. K., (2004). The oil palm and its sustainability. *Journal of Oil Palm Research* 16(1): 1-10

[3] Encyclopedia Britannica, (2017). The Editors of Encyclopaedia (2017) "drilling mud". Encyclopedia Britannica, https://www.britannica.com/technology/drilling-mud. Accessed 9 May 2022.

[4] Caenn, R., (2018). "*Drilling fluid history", Ryen@DrillCompFluids.com*.

[5] Chen, G., Chenvert, M.E. and Sharma, Y.M., (2003). ‘A Study of Wellbore Stability in Shales including Poroelastic, Chemical and Thermal Effects’, *Journal of Petroleum Science and Engineering*, 38(3–4):167–176.

[6] Dosunmu, A. and Joshua, O., (2010). ‘Development of Environmentally Friendly Oil Based Mud Using Palm-Oil and Groundnut-Oil’, *Nigeria Annual International Conference and Exhibition*. Tinapa - Calabar, Nigeria: Society of Petroleum Engineers, p. 9. doi: 10.2118/140720-MS.

[7] Lyons, W., (1996). '*Standard Handbook of Petroleum and Natural Gas Engineering'*. Gulf Publishing Houston Texas USA Vol 1 pp678.

[8] Neff, J. M., McKelvie, S. and Ayers, R., (2000). ‘Environmental Impacts of Synthetic Based Drilling Fluids’, *U.S. Department of the interior minerals managment service*, p. 141.

[9] Offshore Technology Report, (1999). "Drilling Fluid Composition and use within the UK Offshore Drilling Industry "Available at https://www.hse.gov.uk/research/otopdf/1999/oto99089.pdf Accessed on 9th May, 2022

[10] Salleh, A. and Mohd, K., (2005) ‘Palm Oil Derived Esters-An Environmentally Safe Drilling Fluid’, *Malaysian Palm Oil Board*.

[11] Shahidi F (2005). Bailey’s Industrial Oil and Fat Product, Vol. 1 & 6, 6th Edition, A Wiley Interscience Publication, John Wiley & Sons, New York.