Available online at: http://proceeding.rsfpress.com/index.php/ ess/index
LPPM UPN "Veteran" Yogyakarta Conference Series
Proceeding on Engineering and Science Series (ESS)
Volume 1 Number 1 (2020): 284-294

The Effects of VICOIL Bopanprog Usage as a Substitute for Crude Oil for Oil-Based Drilling Fluids

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Abstract

The use of water-based mud often faces some difficulties in dealing with shale zones, which can cause shale problems. Oil-based mud has better performance than water based mud in overcoming shale problems. However, oil-base mud can cause unfavorable environmental impacts, and it is more costly than water base mud. Various efforts were made to find oil base mud materials that are environmentally friendly and do not cost too much money but still function as a standard oil-base mud with all its advantages compared to water-based mud. Oil-based mud by using VICOIL Bopanprog as its liquid phase is expected to be a substitute material for oil-based mud. The first test is to analyze the shale content of the cutting samples, which will be tested on the designed mud by using MBT and XRD. From the results of these tests, we can find out the potential shale problems that will occur. Then we can determine the correct mud composition to prevent the shale problem from happening. To determine the physical and rheological properties of the designed mud, tests are carried out in the laboratory. After meeting the testing standards, the mud filtrate is tested to the cutting sample that has been analyzed at the beginning to determine its performance in overcoming shale problems. From the research results, the use of VICOIL Bopanprog oil-based mud has met the normal oil base mud standard, and it is able to overcome clay swelling caused by smectite and illite minerals from the tested cutting samples. However, in testing, the cutting samples also contain kaolinite minerals, which tend to cause sloughing problems. OBM VICOIL also has good mechanical, hydraulics, and or properties of drilling mud to prevent shale sloughing.

Keywords: Oil Base Mud, VICOIL, Shale

I. INTRODUCTION

Drilling mud is a very vital material in drilling operations. The selection of the right drilling mud is very necessary because of drilling speed, efficiency, and drilling costs are dependent on it.
The function of drilling mud is highly dependent on the physical and chemical properties of the mud. It is very important to control the physical properties of the mud, such as density, plastic viscosity, gel strength, yield point, and filtrate loss, so that the drilling mud functions as it is expected—the chemical properties of the mud related to the physical properties of the mud. One of the challenges in the world of petroleum engineering is how to determine the composition of drilling mud that is

DOI: https://doi.org/10.31098/ess.v1i1.121

cheap, environmentally friendly, and function properly in the drilling operations. In the implementation of drilling, water base mud often face some difficulties in dealing with the shale zone. Shale formation tends to be swelling or sloughing if there is contact with water-based mud.

To solve the shale problem, oil-base mud can be used as a drilling fluid. Because of the filtrate from oil does not hydrate, the clay-like water does. Various researches have been tried on the suitability of various mineral oil from vegetable for use as alternatives to the diesel oil or crude oil. All these have been done in a bid to add that extra margin of safety to man, plant, and animal life in the area where oil and gas are produced. Consequently, access to a full range of vegetable oils for mud formulation is necessary to achieve cost-effective development. The use of mineral oil from vegetable as a base for oil-base mud is expected to be an alternative to answer this problem. This paper would focus on testing the use of VICOIL Bopanprog as a base oil of OBM compared to crude oil base OBM in rheological properties and its performance to handle the shale problem by testing it to cutting from "AW-003" well "WNG" field. To determine the shale problem, we can analyze from the cutting we have by using XRD and MBT test.

II. LITERATURE REVIEW

II.1. Drilling Mud Functions

The main purpose of using mud in drilling is to complete the operation at the lowest possible cost. This can be seen from several of the main uses of drilling mud as follows:

a. Lifting cuttings to the surface
b. Cools and lubricates bit and drill strings
c. Control formation pressure
d. Clean the bottom of the borehole
e. Coating the drill hole with mud cake
f. Supports the weight of the drill pipe assembly and casing
g. Carries cutting and other materials in suspension when mud circulation is temporarily stopped
h. Protect productive formation
i. As a source of information and logging evaluation, media

II.2. Drilling Mud Properties

The ability of mud used in drilling is largely determined by the physical properties shown by the mud, which can be obtained from experiments in the laboratory. The results of the analysis are expected to be able to meet the expected properties used in drilling a formation. The properties that mud must exhibit before use in drilling are density, viscosity, plastic viscosity (PV), yield point (YP), gel strength, filtration loss, and pH.

II.3. Drilling Mud Classification based on The Fluid Phase

II.3.1. Water-base Mud

When the material of mud liquid phase is water, the mud is called water base mud. The water used can be in the form of freshwater or brine water.

II.3.2.Oil base mud and Oil base emulsion

Oil base and oil base emulsion mud contains oil as the continuous phase and water as the dispersed phase. The nature of this mud is not sensitive to contaminants. Oil-based mud, when used, the filtrate of the mud is oil so that it will not hydrate shale or clay when faced with a formation that has the potential to have problems due to shale or clay. In general, the use of oil-based mud:

1. Drilling in the shale formation.
2. Deep drilling and high temperature.
3. Completion fluid.
4. Workover fluid.
5. As a packer fluid.
6. Immersion fluid for pipes stuck.
7. Massive salt zone drilling.
8. Coring fluid.
9. Drilling information contained H_2S and CO_2.

II.4. The Effect of Drilling Mud on Shale Problem

In a drilling operation, there is direct contact between the circulating mud and the walls of the wellbore, resulting in a reaction that affects the properties of the mud, especially in drilling on shale or clay formation (argillaceous). The hydration phenomenon is caused by the interaction between drilling mud and argillaceous formation, which causes an increase in bulk volume of rock and expansion pressure. The conditions identified include the occurrence of sloughing, heaving, expansion (tight hole), and gradual hole enlargement and caving. The characteristics of the five conditions related to the shale problem can be seen and then be used to help identify the shale problem that occurs, and in turn, can be used as a basis for selecting drilling mud to improve the stability of the drilled hole.

Table I. Condition, Characteristics, and Solving Shale Problem
(Lummus and Azar 1986)

Condition	**Characteristics**	**Solving Shale Problem**
Sloughing	Soft, high dispersion (high MBT values).	Oil-based mud dan Water-base mud with KCl.
Heaving.	Soft to medium, interlayered with high *clay* MBT values, Can be an advanced process of sloughing.	Oil-based mud dan Water-base mud with KCl.
Expansion (*Tight hole*)	The high degree of plasticity, high MBT values, forming a gumbo ball.	Increase mud weight, Lumpur fast Minyak, dan Oil base mud dan Water-base mud with KCl.
Gradual hole enlargement	Washout, enlarged borehole diameter, low MBT value but still contained clay, no sloughing or heaving tendency.	*Polymer encapsulation*, *mechanical plugging* in fine fracture

Caving	Dense, deeply buried, low MBT values. Surface hydration can caused cracking, and caving in fragments.	If *montmorillonite*, use *inhibited mud*. If *kaolinite*, use *polymer freshwater mud* or oil-base mud

II.4.1.Types of Shale

Shales are formed from the consolidation of clay and silt on the seabed, forming formations that have a layer or laminate structure. Shales consist of various minerals, such as quartz, feldspar, dolomite, calcite, siderite, and gypsum. This mineral is an inert solid and is not affected by the chemical environment of the drilling mud, although its presence may cause mechanical instability.

Table II. The swelling potential of shale
(*Mufti G*., "*Clay Chemistry"*)

Group	**Structure**	**Cation Exchange**	**Atomic Range**	**Swelling**
Smectite/ Montmorillonite	2:1 layer	Na, Ca++, K+, Mg++	11-15	Varies
Illite	2:1 layer	K+	10	No
Vermiculite	2:1 layer	K+, Mg++	14 – 15	Varies
Tale	2:1 layer	none	9.3	No
Mica	2:1 layer	K+	10	No
Chlorite	2:1 layer	Lapisan *Brucite*	14	No
Sepiolite	2:1 layer	none	12	No
Palygorskite	2:1 layer	none	10.5	No
Kaolinite	2:1 layer	none	7.2	No

Other minerals are kaolinite, illite, chlorite, montmorillonite, and mixed-layer clay, which adsorb water when encounters water-base mud, causing instability of the borehole.

• Montmorillonite clay
Montmorillonite clay consists of two silica tetrahedrons with one alumina tetrahedron in the middle. This arrangement is referred to as a 2: 1 configuration. In contrast to kaolinite, the layer between the two lattices in this crystal is bound by two oxygen sides of the tetrahedral silica. Therefore this bond is not strong and allows water to enter. It causes swelling.

• Illite
The basic structure of illite is the same as the basic structure of montmorillonite. Illite has swelling properties but smaller than montmorillonite.

• Chlorite
The mineral chlorite is the same as illite but less hydrated, made up of the same three layers.

• Kaolinite

Kaolinite is formed by repeating the arrangement of one tetrahedral silica and one octahedral alum, which is characterized as quite strong, consequently not reactive or no swelling.

Table III. Classification of Shale Based on MBT and XRD tests
(Mondshine, 2004)

CLASS	TEXTURE	CEC (meq/100gr)	WATER CONTENT	WATER (wt %)	CLAY CONTENT	DENSITY (g/cm^3)
A	Soft	20 - 40	Free and bound	25 - 70	Montmorillonite dan Illite	1,2 - 1,5
B	Firm	10 - 20	Bound	15 - 25	Illite dan Mixed Layer Montmorillonite Illite	1,5 - 2,2
C	Hard	3 - 10	Bound	5 - 15	Trace Montmorillonite High Illite	2,2 - 2,5
D	Brittle	0 - 3	Bound	2 - 5	Illite, Kaoline, Chlorite	2,5 - 2,7
E	Firm Hard	10 - 20	Bound	2 - 10	Illite dan Mixed Layer Montmorillonite Illite	2,3 - 2,7

II.5. VICOIL Bopanprog Usage as Oil Base Mud

Virgin Coconut Oil (VICOIL) is a processed product from coconut meat that has a clear, tasteless liquid with a distinctive coconut odor—making Virgin Coconut Oil does not require expensive costs because the raw materials are obtained easily. Virgin Coconut Oil contains high to medium and short-chain saturated fatty acids, which are about 92%. Refined coconut oil has chemical-physical properties, including organoleptic (colorless and needle-like crystal). Virgin Coconut Oil (VICOIL) has a specific gravity of 0.883 at 20 ^oC. VCO does not evaporate at a temperature of 21^{0}C, with a melting point of the 20-25^{0}C, boiling point: 225^{0}C, with air density (Air = 1): 6.91. And has a vapor pressure (mmHg) of 1 at a temperature of 121^{0}C. In addition to the various benefits of virgin coconut oil, it can also be used in the petroleum industry as a liquid phase oil base mud with several advantages, namely:

1. Can be used in high-temperature drilling.
2. Have good lubrication.
3. It Does not cause corrosion.
4. Can be used in penetrating water-reactive formations.
5. Can solve shale problems such as swelling.
6. More environmentally friendly than diesel or crude oil.

III. RESEARCH METHODOLOGY

The method used in this research is a laboratory test with the following steps:

III.1. Cutting analysis
The cutting analysis was performed using the X-Ray Diffraction (XRD) and Methylene Blue Test (MBT) method. X-Ray Diffraction analysis using bulk mineral analysis and clay oriented analysis.

a. Bulk Mineral X-Ray Diffraction
Analysis, The first X-ray diffraction analysis was performed using bulk minerals. 5 grams of cutting are smoothed and put into the x-ray diffraction apparatus to be tested, then the dominant mineral type in the cutting sample can be determined based on the test results.

b. Clay Oriented X-Ray Diffraction
Analysis If the bulk mineral contains clay, then the quartz mineral is separated by a sieve, and the XRD test is repeated only for clay (clay oriented). 5 grams of cutting that has been separated from the mashed quartz and put into the x-ray diffraction apparatus to be tested, then based on the results of the clay oriented test, the dominant clay mineral is determined. The clay mineral will show that the formation problem tends to cause some shale problem types.

c. Methylene Blue Test Analysis
5 grams of cutting samples that have been refined and filtered with a mesh size of 200, tested using MBT and determined the texture of the clay, potential problems that will occur, and the type of clay minerals based on the value of cation exchange capacity (CEC).

III.2. Analysis of Drilling Problems Based on Cutting Analysis
Based on the results of the X-ray Diffraction analysis and the Methylene Blue Test analysis, it can be seen that the potential problem of shale (swelling clay or sloughing) that can occur.

III.3. Determination of Drilling Mud Composition
Determining the composition of the drilling mud is carried out by identifying the potential problems that exist at that formation and also the target physical properties of the drilling mud to be achieved.

III.4. Testing of Physical Properties and Rheology of Mud
Testing the physical and rheological properties of oil-based mud using VICOIL and oil-based mud using crude oil in the laboratory, including rheology testing, filtration loss, and pH.

III.5. Testing Mud Filtrates Against Cutting Samples
Oil-based mud filtrate made from VICOIL and oil-based mud made from crude oil was dropped on the cutting samples field "WNG" well "AW-003," and the reaction was observed.

IV. FINDING AND DISCUSSION

IV.1. Cutting Analysis Results
IV.1.1.Methylene Blue Test Analysis
Methylene Blue Test (MBT) was conducted to determine the cation exchange capacity (CEC) of cutting samples. The CEC value will indicate whether the cutting sample is reactive or not. The results of the samples tested can be seen in Figure I.

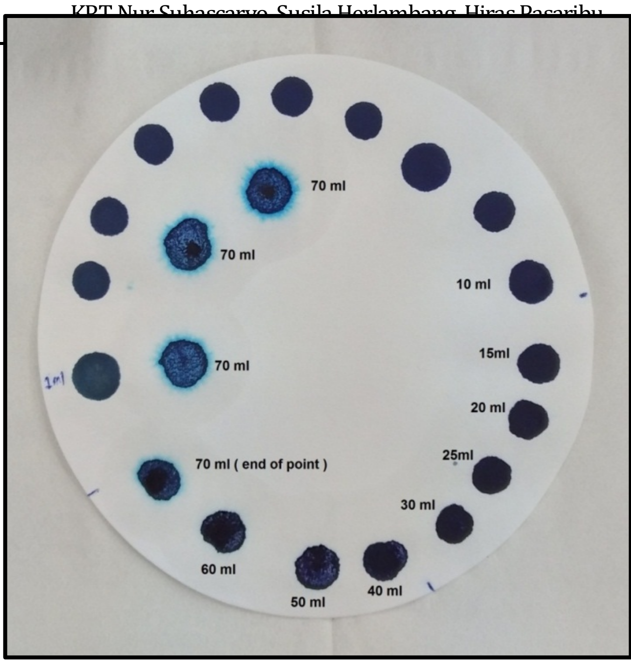

Figure I. Methylene Blue Test Results for Cutting Samples 615-620ft

The results of the experiment cause a dark blue to light blue gradient when it reaches the end of the point. The number of methylene blue droplets required to reach the end of the point indicates the reactivity of the sample.

• Calculation of methylene blue (MBT) cutting sample 615-620ft
CEC = (100 / f) x Vcc x N
= (100/2) x 70 x 0.01
= 35 meq / 100gr

The results of the MBT test for the Well cutting sample "AW-003" depth of 615 - 620 ft, values 35 meq / 100gr clay, according to Table III. The results of the MBT test meet the classification of shale class A with a soft texture, with clay type Montmorillonite and Illite, high dispersion has a tendency to swelling.

IV.2. X-Ray Diffraction Test Analysis
XRD analysis was carried out to identify the type of clay minerals contained in the cutting sample "AW-003". The mineral analysis used XRD with air-dry conditions and after solvation of EG (ethylene glycol). Based on the graphs produced **in Figure II, it shows** the mineral content of smectite, illite, and kaoline.

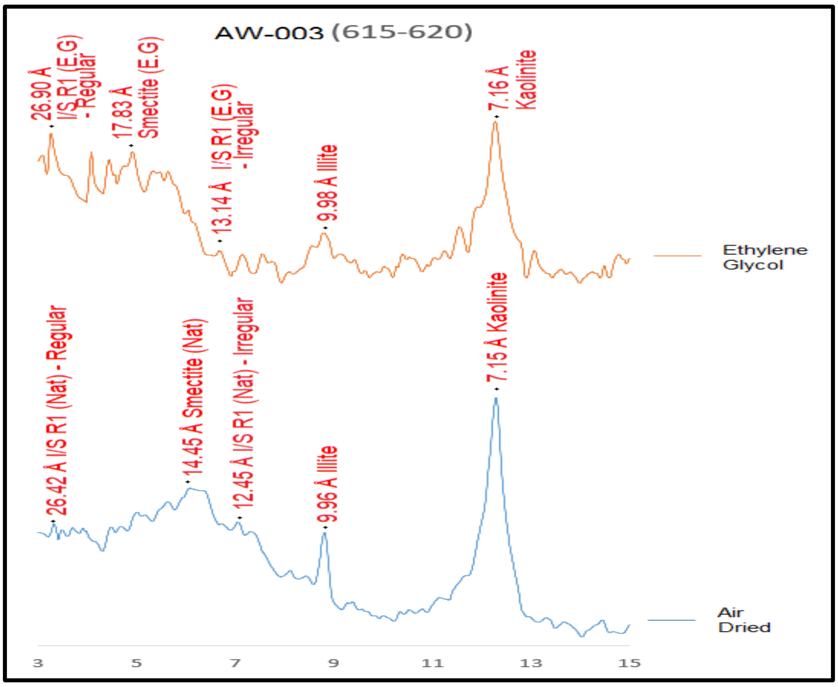

Figure II. X-Ray Diffraction Sample Cutting "AW-003" Depth 615-620ft

Table IV. Mineral Content of Sample Cutting "AW-003" Depth 615-620ft

Kaolinite	Illite	Smectite	Mixed Layer		Total
			I/S R1 - Regular	/S R1 - Irregular	
32.44	14.81	20.59	15.97	16.19	100

The results of XRD analysis on cutting samples with a depth of 615 - 620 ft contained kaolinite mineral, which has no swelling potential in hydrated conditions. However, these cutting samples also contain smectite and illite minerals, which have swelling properties in wet or hydrated conditions.

IV.3. Composition of Tested Oil Base Mud

The design of oil-base mud tested was using two different liquid phases, the first using crude oil as a comparison with the following composition:

Table V. Composition of OBM Design Mud Using Crude Oil

Material	Function	Mud Design Composition
Crude Oil	Base Oil	245 cc
Water	Polar additive	105 cc

CaCl2	Shale Control	30 gr
H. Lime	Alkalinity	5 gr
Barite	Weighting Material	100 gr
Geltone II	Viscosifier	5 gr
Carbatrol HT	Filtration Reducer	5 gr
INVERMUL	Primary Emulsifier	5 cc
EZ MUL	Secondary Emulsifier	2 cc

The results of the oil base mud design using crude oil have physical and rheological properties, as in Table VI.

Table VI. Results of Physical Properties and Rheological Properties of OBM Using Crude Oil

Mud properties	**Test Result**
Mud Weight	9,45 ppg
Plastic Viscosity	56 cp
Yield Point	64 lb/100 sq ft
Gel Strength 10’	30 lb/100 sq ft
Gel Strength 10’’	50 lb/100 sq ft
Filtrate Loss	0,4ml / 30 minute
Mud Cake	0,65 mm
PH	9

The second oil base mud design test was using VICOIL Bopanprog with the following composition:

Table VII. OBM Design Composition Using VICOIL Bopanprog

Material	**Function**	**Mud Design Composition**
COIL Bopanprog	Base Oil	245 cc
Air	Polar additive	105 cc
CaCl2	Shale Control	30 gr
H. Lime	Alkalinity	5 gr
Barite	Weighting Material	100 gr
Geltone II	Viscosifier	5 gr
Carbatrol HT	Filtration Reducer	5 gr
INVERMUL	Primary Emulsifier	5 cc
EZ MUL	Secondary Emulsifier	2 cc

The results of oil-base mud design using VICOIL Bopanprog have physical and rheological properties, as in Table VIII.

Table VIII. Results of Physical and Rheological Properties of OBM using VICOIL Bopanprog

Mud properties	**Test Result**
Mud Weight	10 ppg

Plastic Viscosity	106 cp
Yield Point	18 lb/100 sq ft
Gel Strength 10’	12 lb/100 sq ft
Gel Strength 10’’	15 lb/100 sq ft
Filtrate Loss	7,8ml / 30 menit
Mud Cake	1,3 mm
PH	9

IV.4. Testing Mud Filtrates to Cutting Samples

It was testing oil base mud filtrate designed to overcome the shale problem by dropping 3 ml of each design mud into a measuring cup filled with 3 grams of sample cutting. The test results showed that the sample cutting, which was dripped with the two oil base mud designs, did not experience any reaction after being left idle for 12 hours. The cutting sample, which was dripped with water, only results in an expansion 2 times the original column height. This is due to the mineral content of smectite and illite, which has swelling properties in wet or hydrated conditions in the cutting sample of "AW-003" well in 615-620ft depth. This is confirmed by the results of the MBT test.

V. CONCLUSION AND FURTHER RESEARCH

The use of VICOIL Bopanprog as OBM drilling fluid in "AW-003" well with interval depth of 615ft-620ft has met the normal standard for oil-base mud. In properties observed, water loss according to API standards is below 13.5 ml / 30 minutes so that the invasion of the filtrate does not really affect the formation, and the filtrate of OBM VICOIL, which is oil, does not hydrate the shale as water does. OBM VICOIL Bopanprog is the best type of mud in dealing with clay swelling caused by smectite and illite minerals from cutting samples. However, in testing, the cutting samples also contain kaolinite minerals with hard and non-reactive properties, which tend to cause sloughing problems. Sloughing problems can be caused by mechanical, hydraulic, and or properties of drilling mud. To prevent slouching, it is necessary to pay attention to several things, such as maintaining hydrostatic pressure, optimizing the hole cleaning, and checking the properties of the drilling mud, which aspects have also been fulfilled by the VICOIL OBM design mud.

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