Retrospective Panorama On Application Of Restructured Rectorite In The Formulation Of Eco-Friendly Biodiesel Based Drilling Fluid

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Abstract: The uprising necessity for petroleum results in the swift evolution of drilling techniques in more complicated structure of wells and drilling operations under rough conditions. To meet this non-aqueous phase drilling fluids (NADF) is used to achieve good wellbore stability, thin filter cake, excellent lubricity and low risk of stuck pipe. The NADF is prepared by modification of bentonite with quaternary ammonium salts and addition of clay minerals. In this paper, a newly formulated environmental friendly restructured rectorite and biodiesel based drilling fluid is prepared and discussed.

IndexTerms: Emulsion, Organophilic clay, Organorectorite, Rectorite, Rheology, Suspendability, Swelling behaviour

1. INTRODUCTION

The disposal of drilling fluid after the drilling process is the area of major concern, as it will pollute the environment drastically because it has the toxic level above the prescribed limit. Biodiesel gains attention from petroleum researchers and drilling engineers who are looking for environmentally friendly, cheap and high performance drilling fluids. [2] The availability of biodiesel is also plays a key role in the usage of biodiesel based drilling fluid. According to the World Bioenergy Association (2017), the global biodiesel production was increased to 38 folds in 2014. i.e., 32 billion litres from 0.84 billion litres in 2000 within 14 years. [3] The major advantageous properties of biodiesel is it's high flash point, sufficient viscosity, low toxicity, high biodegradability and excellent lubricity which makes the way for biodiesel as a base fluid for preparation of drilling fluid.[4]

2. Abbreviations and Acronyms

BBDF – Biodiesel Based Drilling Fluid
OR – Organorectorite
OB - Organobentonite

3. Organophilic clays – A base material

The outer surface of the clay minerals have been coated with a chemical to make them oil dispersible. The organophilic clays which is used for drilling fluids is prepared by addition reaction between bentonite and quaternary ammonium salts but it has some disadvantages such as low degradation and high toxicity.[5] It is evident that, we have to select a material other than bentonite to mitigate the above disadvantages. Usage of rectorite mineral with smaller modifications will yield a better results.

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3.1 Rectorite

Rectorite is a clay mineral formed by dioctahedral mica layer and dioctahedral smectite layer with a 1:1 type of layer structure and a peculiar banded structure. Similar to bentonite, Rectorite also has excellent colloid properties such as swelling and gelation in water, which indicates its potential for being organophilized. [3, 5] The intramolecular bonding between rectorite crystal layers is weak which facilitates the cation exchange on the external surface. This eases the addition of wetting agents with rectorite.
At present, Rectorite is found in more than 40 locations around the globe and is mainly found in China. The utilization of Rectorite is very low which enables the product available at 10-20% cheaper than bentonite in China. [4, 6] This facilitates the formulation of Organorectorite (here after referred as OR) for BBDF will reduce the costs for drilling operations.

3.2 Manufacture of Restructured Rectorite

Unionized wetting agents were chosen to modify the wetting property of the rectorite through addition reaction. Formulation of OR is based on a suspension production technique with unionized wetting agents. To produce OR, the raw rectorite has to experience three modification steps namely pre-treatment, reaction and purification. This process is simple and form uniform products in terms of size and property. [7] In order to obtain the high quality of Organorectorite temperature, agitation rate, pH, reaction time and number of washing required has to be customized based on the feedstock.The selection of unionized wetting agents is not only based on the quality and property of raw rectorite, it also depends on the base fluid used for the preparation of drilling fluid. For BBDF, researchers suggests that the wetting agents with some unsaturated carbon bonds can produce OR which have good swelling behaviour in biodiesel emulsion.[8] It is due to the fact that many of the esters in biodiesel have unsaturated bonds, which is similar to that of the wetting agents. As a result of this, the interaction between biodiesel and OR is enhanced and it shows better degree of swelling. X-ray diffraction analysis showed that the basal spacing of rectorite increased from 1.097 to 1.619 nm after organophilization, which reflects the high degree of addition.

3.3 Fundamental Property Evaluation

3.3.1 Composition and Structure

Laboratory tests were conducted to characterize the OR through chemical analysis. A commercial Organobentonite (here after referred as OB) also tested for comparative study. Fundamental properties such as appearance, density, basal space, particle size, grain size and organic material content of OR and OB are listed in Table 1. Properties such as density and particle size are similar but the basal size of OR is higher than that of OB (d_{001} OR > d_{001} OB), which shows its lower crystal structure. This loose structure favours the entry of biodiesel into the OR and form the thixotropic biodiesel-based gel required by drilling fluid rheology.

Table 1 – Fundamental Properties of OR & OB

Property	OR	OB
Appearance	Grey powder	White powder
Density (g/cm^3)	1.78	1.69
Basal space (nm)	1.619	1.200
Particle size (µm)	< 75 (200 mesh)	<75 (200 mesh)
Grain space (nm)	31.5	25.8
Organic material content (g/g clay)	17.2	11.9

3.3.2 Swelling Test

The swelling ability of OR and OB in base fluid were tested with procedures of American Society for Testing and Materials (ASTM) standard D5890 (2011), which is for water-swell clay minerals.[9,11] In these tests, we replaced water with biodiesel, diesel, white oil and the invert emulsions of these three oils.

The Swelling index is calculated by using the equation,

$$SI = V_{sw} / m_c$$

Where,

V_{sw} – Volume of swelled organoclay (ml)

m_c – Weight of clay, 2g

The Swelling Indices of OR and OB in different organic liquids are presented in Table 2.

Table 2 - Swelling Indices of OR and OB in different organic liquids

Component	Swelling Index (ml/2g)	
	OR	OB
Biodiesel	8	6
Diesel	7	7.5
White Oil	5	9
Biodiesel emulsion	13.5	9.5
Diesel emulsion	12.0	12.5
White Oil emulsion	8.0	14.0

From the table 2, it is evident that the swelling indices of OR in biodiesel and biodiesel emulsion is good in comparison with OB and vice-versa in white oil and white oil emulsion. This implies that OR is better suitable for BBDF. Generally, the swelling behaviour of the organophilic clays in emulsion is greater than pure oil because of the partial ionization of organophilic clays. Emulsified water droplets are probably helpful for swelling, especially in the presence of wetting agents. From this, it is suggested to use biodiesel emulsion for further research.

3.3.3 Emulsion Rheology Test

Viscosity growth rates of the biodiesel emulsion with various organoclays (1.2 wt%) such as OR and OB under high rpm is studied. This study reveals that both OR and OB has increased apparent viscosity and yield point with increase in rate of agitation. The time required to reach the apparent viscosity for both the organophilic clays were similar but OR reaches the yield point quicker than OB. This indicates that OR can disperse and swell in biodiesel emulsion faster. The viscosifying ability of OR is high in comparison with OB which shows its high efficiency in biodiesel emulsion.

3.3.4 Electrical Stability Test

The stability of invert emulsions is controlled by adding organoclay, thus in turn controls the stability of drilling fluids. OR enhances the electrical stability by nearly 200V, while OB responds upto few volts. Quite a few number of surface active organoclays can move to the interface of oil/water and strengthen the film formed by emulsifiers, generating a pickering emulsion. As a result of this, the droplets have more difficulty in accumulation after they collide with each other, ascertain the emulsion stability.

3.3.5 Near-Infrared Spectroscopy Test

A near-IR spectroscopy test based on the multiple-light scattering technique was applied to analyse the stability of the biodiesel emulsion containing organoclays. It gives an appropriate method to look into the stability of emulsion, which is a majorly obtained from traditional ES test.[11] The stability indices of the biodiesel emulsions containing organoclays were calculated from the standard readings which shows a lower stability index means greater emulsion stability.

3.4 Determination of properties of newly designed BBDF with OR

3.4.1 Rheology and Filtration

A newly formulated BBDF was developed to predict the eligibility of OR along with the emulsifiers, rheological modifiers and fluid loss control agents. The properties such as electrical stability, basic rheological properties and high temperature, high temperature/high pressure fluid loss (HP/HT FL) volume is calculated [1] [9]. The rheological trend of BBDF is comparatively linear, which results in smooth equivalent circulation density and ensure well control during drilling. The plastic viscosity decreases with increase in temperature. The 6rpm reading and yield point varies slightly with temperature irrespective of the density of BBDF. Gel strength and HP/HT FL results are within the permissible limit.[11] This shows that the rheological and filtration behaviour of BBDF can be controlled by using the proper combination of OR and rheological modifiers.

3.4.2 Suspendability

Sagging of weighting materials in drilling fluid is a complex process. In the process of drilling fluid circulation, the fluid thins when it reaches the bottom hole which leads to increased risk of sagging. Static barite-sag tests were carried to calculate the suspendability of BBDF. [9] The results shows that BBDF have satisfactory suspendability. From this, it is advised to maintain an appropriate combination of organoclay and rheological modifiers to achieve the suspendability of BBDF.

3.4.3 Environmental Acceptability

The newly developed BBDF containing OR is tested for Chinese standard using environmental requirement and test methods and found to be nontoxic. When BBDF is placed in aerobic biodegradation test, the BBDF degraded by 75% in 28 days whereas the OBDF degraded only by 38.5%. Under anaerobic condition for 60 days, the BBDF degraded by 62.2% whereas OBDF degrades only by 32.9%. [10] These results shows that both BBDF and its additive OR is having good environmental acceptability in the drilling operation.

4. CONCLUSION

- OR can be produced by altering the wettability of interlayer space of rectorite upon the addition of unionized wetting agents.
- The swelling behaviour of OR in a biodiesel invert emulsion shows its excellent rheological properties.
- The stability of BBDF can be enhanced by adding OR.
- Excellent rheology and Suspendability at high temperature of BBDF is obtained by using OR as high efficiency viscosifier.
- OR in combination with BBDF offers smooth drilling operations under extreme conditions.
- The cheaper availability of rectorite makes it cost effective.

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