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Mixed Mineral Thixotrope Suspension Aid in Oil-based Drilling Fluids for ECD Management

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Abstract

In oil-based drilling fluids it can be difficult to achieve acceptable barite suspension and hole cleaning while at the same time maintaining pump pressures that do not exceed the fracture gradient of the formation. An ideal suspension aid would be something that can be added to an organoclay containing fluid and only increase the low shear viscosity that is required for solids suspension. A study was conducted to determine the effectiveness of a mixed mineral thixotrope suspension aid (MMTSA) at reducing barite sag without negatively affecting the PV of the fluid. The MMTSA was added to an organoclay containing fluid and rheology measurements were taken initially and after hot rolling at 250°F.

Rheological data for the fluids was recorded, but particular attention was paid to the Plastic Viscosity (PV) and the 6-rpm dial readings. Greater PV values would indicate increases in ECD in the field, while higher 6-rpm values suggest improved hole cleaning. Dynamic sag (VSST) was also monitored as an indicator of barite sag tendencies.

Rheological testing on a hot-rolled mud containing only 8.5 lb/bbl organoclay showed a PV of 29 cP and a VSST of +3.46 lb/gal. To test the MMTSA, the organoclay content was lowered to 7.0 lb/bbl and 1.0 lb/bbl of MMTSA was added to the fluid. Rheological testing on the hot-rolled mud containing organoclay and MMTSA showed a PV of 28 cP and a VSST of +2.46 lb/gal. The results indicate that the inclusion of MMTSA can reduce barite sagging without increasing the ECD of the drilling fluid.

Introduction

In drilling operations, it can be very difficult to manage drilling fluid rheology in such a way that it provides good suspension for barite and hole cleaning, but at the same time flows at low enough pump pressures to avoid exceeding the fracture gradient of the encountered formations. Traditional oil-based drilling fluids utilize organoclay viscosifiers. Organoclay viscosifiers provide viscosity across the entire shear range in drilling operations. This means that organoclay additions required to boost the low end rheology (6-rpm and YP) to provide barite suspension and hole cleaning will also dramatically increase the PV of the drilling fluid which will translate into higher ECDs in the field. Ideally, mud engineers would have a toolbox of additives that they could used to alter the rheology of the drilling fluids in a certain shear range. Doing so would allow them to alter drilling fluid properties such as 6-rpm and YP without affecting the PV of the fluid. It now appears that it is possible to accomplish this task with the introduction of MMTSA to the market.

A study was conducted to determine the effectiveness of MMTSA at providing rheology in the low-shear range to boost 6-rpm and YP without affecting the high-shear range rheology and the PV of the drilling fluid. The MMTSA was added to an organoclay containing drilling fluid at two different ratios. Rheology was measured initially and then after hot rolling overnight for 16 hours at 250°F. Selecting the right ratio of organoclay to MMTSA can provide a drilling fluid that performs in the low-shear range without negatively impacting the PV and by relation, ECD of the fluid.

MMTSA Chemistry

Mixed mineral technology involves the blending of acicular and platey minerals. The minerals, which are hydrophilic in nature are subject to a refining process which removes greater than 99% of the inert contamination associated with the minerals. The mixed minerals are then surface modified to render them hydrophobic so they will disperse and provide rheology in base oils. The choice of surface treatment is dependent on the type of base-oil that is being used in the drilling fluid. Figure 1 is an illustration of how MMTSA differs physically from traditional organoclay. The mixed mineral technology leads to random packing of the material when in a dry powdered form. The random packing allows fast solvation of the MMTSA and to very fast and easy dispersion using only modest amounts of mixing shear.

MMTSA were originally developed for thermoset composite and coatings applications. They provide suspension of solids and anti-sagging properties while maintaining a low overall system viscosity for ease of application. Due to the fact the MMTSA requires less solvent to disperse than other commonly used viscosifiers in coatings and thermosets, the solvent content can be lowered in the systems without affecting system performance. The results is that coatings and composites can be manufactured with a significantly lower VOC content then similar coatings or composites which utilize other common viscosifiers.

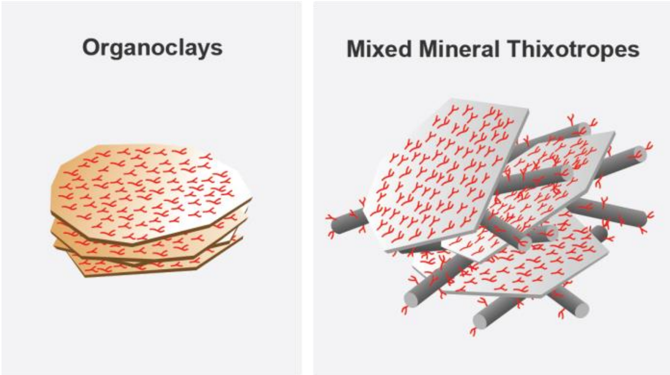


Figure 1. Physical forms of organoclay and MMTSA.

Since MMTSA had commercial success in coating applications, similar results were expected for nonaqueous drilling fluids. The MMTSA should provide low-shear rheology without the onset of (high shear rate) viscosity. In other words, it should raise the 6-rpm and YP of the drilling fluid without affecting the PV. Figure 2 illustrates the typical viscosity versus shear curve for both organoclays and MMTSA.

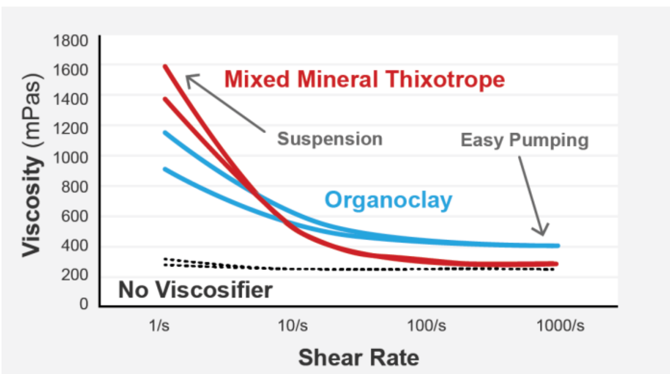


Figure 2. Viscosity profiles of organoclay and MMTSA.

It was quickly determined that MMTSA should not be a primary viscosifier in invert muds. Using MMTSA without organoclay will result in viscosity inefficiency. The MMTSA should be added as a low dosage, secondary suspension agent. Moreover, MMTSA does not offer the fluid loss properties that traditional platey organoclays do. Therefore, if the MMTSA is used as the sole viscosifier, not only will viscosity efficiency suffer, but fluid loss will increase significantly. A unique feature of the MMTSA is that it is stable at high temperatures and can be used as the suspension aid in drilling fluids that will be subject to well in excess of 400°F.

Test Formulation and Experimental Method

To study the effects of the addition of a MMTSA into an organoclay containing oil-based drilling fluid, a test fluid system was prepared using commercially available materials. The system used diesel as the base fluid. The drilling fluid was formulated to 12.0 ppg and had a 75/25 oil to water ratio. The internal phase was a 25% weight to volume calcium chloride brine. The brine was emulsified with a commercially available combination emulsifier/wetting agent. The organoclay content was either 7.0 or 8.5 lb/bbl. The MMTSA addition was 1.0 lb/bbl. API grade barite was used as the weighting agent. Drill solids were not incorporated into the formulation, so the evaluation was on a "clean mud."

The formulation was evaluated for rheology and emulsion stability following API 13B-2 procedures for oil-based drilling fluids. Rheology and emulsion stability values were measured using an OFITE 900 viscometer and OFITE emulsion tester model 131-50. Formulation 1 shows the components and mixing order. After low-shear mixing, the fluid was homogenized at 6,000 rpm until the fluid reached 150°F to ensure stability. Rheological properties were measured at 120°F. The fluid was then transferred to heat aging cells, pressurized, and then hot rolled overnight at 250°F.

Formulation 1. 12 ppg 75/25 Diesel Based Mud

	lb/bbl	Mix Time (min)
Diesel #2	211.1	
Organoclay	7.0 - 8.5	5
MMTSA	0 – 1	5
Lime	3	5
Emulsifier	5	5
25% $CaCl_2$ Brine	75.3	10
API Barite 4.1	220	5
High sheer on Silverson overhead mixer at 6,000 rpm until 150°F		

After removing the aging cells from the roller oven, they were allowed to cool to ambient temperatures before being vented and opened. After removing the fluid from the aging cells the fluid was mixed prior to rheological and emulsion stability testing. The result summary of the testing on Formulation 1 can be seen in Table 1.

Table 1. Results for Organoclay Only (Base Mud)

Organoclay 7.0 lb/bbl		
	BHR	AHR at 250°F
PV (cP)	23	24
YP (lb/100 ft^2)	12	17
6-rpm	6.2	7.9
ES (V)	221	385

The results in Table 1 show a relatively thin mud after mixing. The low shear rate rheology (6-rpm) would be low for most applications.

Table 2. Results for Additional Organoclay

Base Mud with 1.5 lb/bbl Organoclay		
	BHR	AHR at 250°F
PV (cP)	25	29
YP (lb/100 ft^2)	18	14
6-rpm	9.0	10.0
ES (V)	336	451

The results in Table 2 illustrate that an additional 1.5 lb/bbl of organoclay increased the PV greater than the 6-rpm dial reading.

Table 3. Results for Organoclay with MMTSA.

Base Mud with 1.0 lb/bbl MMTSA		
	BHR	AHR at 250°F
PV (cP)	24	28
YP (lb/100 ft^2)	21	21
6-rpm	9.8	13.6
ES (V)	387	367

Table 3 shows that the combination of organoclay and MMTSA provided a 36% increase to the 6-rpm dial reading with a similar increase of PV compared to the 1.5 lb/bbl additional organoclay.

Table 4. Comparison of the Base Mud, Additional Organoclay and Organoclay/MMTSA.

Organoclay 7.0 lb/bbl AHR at 250°F	
PV (cP)	24
YP (lb/100 ft^2)	17
6-rpm	7.9
ES (V)	385
VSST at 120° F	3.96

Organoclay 8.5 lb/bbl AHR at 250°F	
PV (cP)	29
YP (lb/100 ft^2)	14
6-rpm	10.0
ES (V)	451
VSST at 120° F	3.46

Organoclay 7.0 lb/bbl and MMTSA 1.0 lb/bbl AHR at 250°F	
PV (cP)	28
YP (lb/100 ft^2)	21
6-rpm	13.6
ES (V)	367
VSST at 120° F	2.46

Table 4 shows the obvious benefits of MMTSA over the Base Mud and adding additional organoclay.

After reviewing the traditional organoclay results, the authors also decided to test another commonly used suspension aid, organo-attapulgite. Organo-attapulgite can be found commercially in the market under several trademarked brands. Given the commercial use of organo-attapulgite in the market today, the authors decided to include it in the study as another point of comparison. Table 5 shows the results of the comparison of organo-attapulgite to MMTSA.

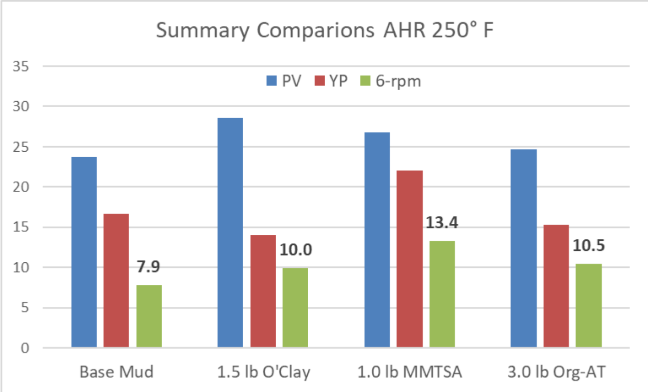
Table 5. Comparision of Organo-attapulgite to MMTSA.

Organoclay 7.0 lb/bbl and Organo-attapulgite 3.0 lb/bbl AHR at 250°F	
PV (cP)	25
YP (lb/100 ft^2)	15
6-rpm	10.5
ES (V)	366
VSST at 120° F	2.85

Organoclay 7.0 lb/bbl and MMTSA 1.0 lb/bbl AHR at 250°F	
PV (cP)	28
YP (lb/100 ft^2)	21
6-rpm	13.6
ES (V)	367
VSST at 120° F	2.46

Table 5 clearly shows that MMTSA at only 1/3 the addition level of organo-attapulgite dramatically improved both the dynamic sag and 6-rpm values while having a relatively small negative effect on PV.

Table 6. Summary Graph of Base Mud, Additional Organoclay, MMTSA, and Organo-Attapulgite.



Conclusions

It is possible to increase the suspension properties of a conventional mud with minimal increases in plastic viscosity with the use of MMTSA technology. The mud system can be further optimized with a ladder study to maximize the 6-rpm values while maintaining or reducing the overall viscosity of the system.

Acknowledgments

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Nomenclature

Organoclay	*=quaternary ammonium compound treated clay*
°F	*=Degrees Fahrenheit*
YP	*=Yield Point*
PV	*=Plastic Viscosity*
6-rpm	*=dial reading at 6 rpm on OFITE 900 Viscometer*
ppg	*=pounds per gallon*
lb/bbl	*=pounds per barrel*
75/25	*=volume ratio of 75% base fluid and 25% brine*
ECD	*=Equivalent Circulating Density*
ES	*=Electrical Stability*

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