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Novel Oil Based Mud Additive Decreases HTHP Fluid Loss and Enhances Stability

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Abstract

Drill-Sure™ OBM Additive, a novel oil based drilling fluid additive, significantly reduces High Temperature High Pressure (HTHP) fluid loss and enhances emulsion stability. Laboratory tests using diesel, mineral and synthetic oil invert emulsion drilling fluids have shown significant reductions in HTHP fluid loss. In field trials product concentrations of 1.5 – 2.5 lb_m/bbl resulted in HTHP fluid losses of 5 – 10 mL/ 30 min. The product also enhanced invert emulsion fluid stability as evidenced by an increase in electrical stability (ES). Laboratory and field results are discussed.

Introduction

Drilling operations are continually searching for improved methods and products for their operations. Performance, cost effectiveness, and supply availability are all important criteria in product selection. A novel additive for use in invert emulsion drilling fluids, Drill-Sure™ OBM Additive (the HTHP additive), has been developed and successfully used in multiple field trials. The HTHP additive was developed to provide superior HTHP fluid loss control as well as providing an available alternative to uintaite (uintahite), commonly referred to by its trademark name, Gilsonite®[1]. The HTHP additive has shown effectiveness in diesel, mineral oil, and synthetic oil based invert emulsion systems.

High fluid loss can lead to increased cost, excessively thick filter cakes, increased torque and drag, increased equivalent circulation density (ECD), difficulties tripping pipe and running casing, substandard cement jobs, and even differential sticking. High temperature high pressure HTHP fluid loss control is a special area of concern and an area for constant improvement in both aqueous based and non-aqueous based drilling fluids. HTHP fluid loss in invert emulsion drilling fluids can be difficult and costly to control due to the nature of the system and the fact that there are limited product types available to effectively reduce HTHP. Asphalt, uintaite, polyamide resins, and styrene copolymers are commonly used to supplement the inherent fluid loss control of the invert emulsion. Organophillic clay contributes to both rheology and fluid loss control.

It was determined that a product that provided improved HTHP fluid loss control without significantly affecting rheology or detrimentally impacting electrical stability (ES) was needed by the industry. The result was the HTHP additive discussed in this paper.

Laboratory Development

Potential candidates were evaluated in laboratory diesel based, mineral oil based, and synthetic oil based drilling fluids. The initial base fluid used for screening was a 14 lb_m/gallon (1.68 kg/L) diesel oil invert mud employing organophillic clay, lime, emulsifiers, and wetting agents. The oil water ratio (OWR) was 75:25 with the brine phase containing 29 weight % $CaCl_2$. The fluid formulation is presented in Table I and a summary of the test results in Table II.

Uintaite was used as a reference control HTHP fluid loss additive. The HTHP additive and the control both increased the rheology of the base fluid, initially and after hot rolling. The initial plastic viscosity (PV) increase was approximately 25% by both products. The PV of the base fluid and the control exhibited a normal decrease after hot rolling. However, the fluid containing the HTHP additive actually showed a modest PV increase after hot rolling 16 hours at 300 °F (149 °C). A similar effect was observed in yield point (YP). Both the HTHP additive and the control exhibited approximately 10% higher initial YP than the base fluid. After hot rolling, the YP decreased in all cases with the HTHP additive maintaining a slightly higher YP than the base fluid or uintaite control. Gel strengths did increase, with the HTHP additive exhibiting higher gel strengths. The gel strengths were essentially flat between 10 minutes and 30 minutes. HTHP fluid loss was low for all the fluids, including the base mud. The HTHP of the fluid containing uintaite was reduced by 46% compared to the base fluid. The HTHP of the fluid containing the HTHP additive was reduced by 65% compared to the base fluid.

The HTHP additive was tested at 6 lb_m/bbl in a 14 lb_m/gallon laboratory mineral oil base mud. Results were similar to those of the diesel oil base mud with minor effects on rheology and gel strength. HTHP fluid loss using both filter paper and 20 um rated ceramic filter disks decreased to less than 3 mL/30 minutes.

A synthetic (olefin-ester blend) base fluid was provided by a service company for evaluation of the HTHP additive in their specific formulation. Samples of the base drilling fluid and the fluid treated with 2.6 lb_m/bbl of the HTHP additive were hot rolled (250 °F) overnight. The HTHP additive did reduce rheology of the fluid compared to the base fluid as shown in Table III. However, HTHP fluid loss at 250 °F was dramatically improved. The base fluid, after hot rolling, had no fluid loss control. Addition of 2.6 lb_m/bbl of the HTHP additive reduced the HTHP to 9.2 mL.

Table I. Diesel OBM Formulation

Base Fluid (Components mixed in order as listed)	Units	Quantity
Diesel	bbl	0.537
Organophillic Clay	lb_m/bbl	6.0
Lime	lb_m/bbl	5.0
Emulsifier	lb_m/bbl	8.0
Oil wetting agent	lb_m/bbl	4.0
Tap water	bbl	0.178
CaCl2	lb_m/bbl	25.3
Barite	lb_m/bbl	312.9
Density	lb_m/gallon	14.0
OWR		75 : 25
$CaCl_2$ Brine Concentration		29%

Table II. Results of Laboratory Diesel OBM

Sample	Base Fluid		Base Fluid + 6 lb_m/bbl uintaite	
	Initial	AHR[1]	Initial	AHR[1]
600/300 (RPM)[2]	105/76	77/50	124/88	90/57
200/100 (RPM)[2]	63/49	40/29	73/56	45/32
6/3 (RPM)[2]	28/26	14/12	31/29	14/13
Gel Strengths, (10s/10m/30m) (lb_f/100 ft^2)	26/30/30	13/17/17	29/33/33	16/21/21
Apparent Viscosity (cPs)	52.5	38.5	62	45
Plastic Viscosity (cPs)	29	27	36	33
Yield Point (lb_f/100 ft^2)	47	23	52	24
Electrical Stability @ 150° F (volts)	992	788	1074	854
API HTHP F.L. (mL/30 minutes)	-	11.9	-	6.4
Filtercake Thickness (mm)	-	2.0	-	1.6

Table II. Results of Laboratory Diesel OBM (cont.)

Sample	Base Fluid + 6 lb_m/bbl Lab Batch A		Base Fluid + 6 lb_m/bbl Lab Batch B	
	Initial	AHR[1]	Initial	AHR[1]
600/300 (RPM)[2]	129/92	108/67	122/86	118/77
200/100 (RPM)[2]	76/59	52/36	72/56	61/44
6/3 (RPM)[2]	35/34	17/16	33/32	22/20
Gel Strengths, (10s/10m/30m) (lb_f/100 ft^2)	38/50/51	27/46/47	36/44/47	32/50/51
Apparent Viscosity (cPs)	64.5	54	61	59
Plastic Viscosity (cPs)	37	41	36	41
Yield Point (lb_f/100 ft^2)	55	26	50	36
Electrical Stability @ 150° F (volts)	1204	700	1040	948
API HTHP F.L. (mL/30 minutes)	-	4.3	-	4.1
Filtercake Thickness (mm)	-	1.5	-	1.7

1: AHR After Hot Rolling for 16 hours @ 300 °F (148.9 °C)

2: Rheology measured @ 150 °F (65.6 °C)

3: API HTHP fluid loss @ 500 psi (3450 kPa) differential pressure, 300 °F (148.9 °C)

Table III. A Synthetic (olefin-ester blend) base fluid.

Property	Base Fluid	Base Fluid + 2.6 lb_m/bbl HTHP additive
PV / YP	27.6 / 6.5	21.8 / 3.5
6 rpm / 3 rpm	1.7 / 1.3	0.8 / 0.5
Gel Strength 10 sec / 10 min (lb_f/100 ft^2)	3.1 / 7.8	2.0 / 6.6
ES (volts)	356	398
Filtrate mL	16 mL in 30 seconds	4.6
HTHP FL (filtrate volume X 2) mL	No Control	9.2

Field Trials

Well 1

The first field trial for the HTHP additive was conducted in Karnes County, Texas in the Eagleford shale play. The diesel OBM used for the first trial had been used on three previous jobs and utilized uintaite and styrene based polymer to control the HTHP fluid loss. As per the operator, the HTHP requirement was 12-14 mL in the vertical section, then 10-12 mL through the curve and lateral sections. The electrical stability (ES) was to be maintained between 300-400 volts and the water phase salinity range between 225K-250K mg/L chlorides. For this field trial the HTHP additive would be used exclusively to maintain the HTHP fluid loss. The surface interval was drilled with water based mud (WBM) and surface casing set at 5,220 feet. The temperature profile for this well was moderate with a temperature of 150 °F at the shoe, 215 °F at the top of the curve, 220 °F at the bottom of the curve, with the lateral reaching 260 °F.

Day 1: After setting surface casing, the diesel OBM from the previous job was transferred into the rig pits, and the WBM was displaced out of the hole. The OBM was centrifuged to remove solids, which reduced the density from 11.9 lb_m/gallon to 10.3 lb_m/gallon. A mud check was conducted after two complete circulations. The HTHP was 10 mL; no treatment was required. The evening mud check was conducted at 6,815 feet, and the HTHP had increased to 14 mL.

Table IV. Well 1 Initial Mud Properties

MW	PV	YP	ES	HTHP (250 °F)	OWR	LGS (wt%)
10.3	11	8	484	10	72/28	6.3

Day 2: Drilling resumed after 12 hours of mud pump repair and tripping time. One-half lb_m/bbl HTHP additive was added to mud system. Three hundred barrels of used OBM were added into the active system to maintain pit volume. The evening mud check was done at 9,100 feet; the HTHP had decreased to 10 mL. The mud engineer increased the concentration of the HTHP additive to 1 lb_m/bbl. Five hundred fifty barrels of virgin mud were delivered to location for makeup volume. The kick off point (KOP), 10,287 feet, was reached, and a trip was made to pick up new directional tools.

Day 3: The trip for directional tools occurred without incident. Drilling resumed, and the mud was checked after 2 circulations. The HTHP fluid loss had decreased to 9 mL. While building the curve, 100 bbls of fresh mud was transferred in, and the HTHP additive concentration was maintained at 1 lb_m/bbl.

Day 4: Hole volume was maintained with diesel oil while continuing to build the curve. One lb_m/bbl HTHP additive was maintained in the system, and the HTHP fluid loss remained at 9 mL. The mud density was increased to 10.8 lb_m/gallon according to the weight up schedule. Once the hole angle reached 50 degrees, tandem low viscosity and weighted sweeps were pumped to aid with hole cleaning. The low viscosity sweeps were made by adding approximately 15 barrels of diesel to 35 barrels of mud from the active system. The evening HTHP fluid loss had increased to 12 mL. The HTHP additive concentration was increased to 1.5 lb_m/bbl. The mud density was increased during the night to 11.2 lb_m/gallon to control background gas.

Day 5: The morning mud check showed the HTHP fluid loss had decreased to 8 mL with a 1.5 lb_m/bbl concentration of the HTHP additive. The mud motor failed. The rig tripped for a new bit and motor without incident.

Day 6: Drilling resumed, and the curve section was completed. The morning mud check reported the HTHP fluid loss had increased to 25 mL. It was determined the sample most likely included some unincorporated low viscosity sweep. To be on the safe side, the mud engineer increased the HTHP additive concentration to 2.0 lb_m/bbl. The evening mud check showed that the HTHP fluid loss had decreased to 8 mL. The mud density was increased during the night to 11.8 lb_m/gallon to control background gas.

Day 7: The drilling of the lateral continued without incident. No additional HTHP additive was added which allowed the HTHP fluid loss to increase into the desired range of 10-12 mL.

Day 8: TD was reached at 16,210 feet. The final HTHP fluid loss was 12 mL at a concentration of 1.5 lb_m/bbl HTHP additive in the mud system. There were no reported problems while running casing.

The HTHP additive performed very well with respect to HTHP fluid loss. Typically the mud company uses an average of 6,000 lb of uintaite and 1,000 lb of a styrene based polymer per job. This well only used 4,700 lb of the HTHP additive. Table V shows the HTHP additive used in this field trial compared to fluid loss additives used previously. Typically, a single centrifuge is run continuously during drilling to help lower the low gravity solids in the mud. The mud engineer felt their setup stripped out a large portion of the uintaite. Running the centrifuge had no effect on the HTHP fluid loss, for this system. The centrifuge was run during trips as well to help clean the mud, and there was never any jump in the HTHP fluid loss after trips. Due to the low ES of the OBM, the OBM retention on the cuttings was very high. It was impossible to notice any loss of HTHP additive over the shaker screen. However, due to the performance of the product it is unlikely any was lost over the 200 mesh screens. The operator's relatively high HTHP fluid loss requirement was achieved with low HTHP additive concentrations. With regards to torque and drag there was little room for improvement. The trips went without incident and the 5,000 foot laterals typically drilled in this area don't have many issues with torque. Beginning with a fresh untreated mud would allow for a greater concentration of HTHP additive to be incorporated into the mud and allow for the possibility of benefits to rate of penetration (ROP), torque and drag.

Table V. Fluid Loss Additive Concentration Comparison.

	Field Trial	Previous Fluid Loss System	
Per Well	HTHP Additive	Uintaite	Styrene based Polymer
Average Amount Used	2.0-2.5 lb_m/bbl	4-5 lb_m/bbl	0.25-0.85 lb_m/bbl

Well 2

Based on the results of the first trial, the operator and service-company elected to use the HTHP additive in a second well in Karnes County, Texas in the Eagleford shale play. After setting surface pipe at 5,227 feet, the water based fluid was displaced with a 10.5 lb_m/gallon new (unused) diesel OBM, so there were no residual fluid additives in contrast to the used mud in the first trial.

Table VI. Well 2 Initial Mud Properties

MW	PV	YP	ES	HTHP (250 °F)	OWR	LGS %
10.5	22	11	361	18	74/26	5.1

Once the new diesel OBM was circulated, the HTHP additive was added to an initial concentration of 0.9 lb_m/bbl. The concentration was increased in stages to achieve the recommended HTHP fluid loss of 10 mL/30 min. This was reached with an HTHP additive concentration of 2.2 lb_m/bbl. The well was drilled to a total depth of 16,107 feet MD in 6 days with a final mud density of 11.8 lb_m/gallon. The mud recovered from the first trial was used to supplement mud volumes in the second trial. As in the first well, low viscosity, weighted sweeps were pumped every 500 feet in the horizontal section as a standard recommendation by the service company.

Rate of Penetration for the 2nd intermediate section (5,221 feet to 10,235 feet) of the well was 233 feet per hour which included connection times. The company man and mud engineer both reported that this was the fastest they had ever drilled this interval. There were no problems pulling the first 10 stands when tripping out to lay down the drill string. The maximum hook load was 274 K lb_f. The mud engineer reported that a normal hook load range for previous wells had been between 290-300 K lb_f.

Well 3

The third field trial was conducted in Roger Mills County, Oklahoma. Casing was set at 7,745 feet, and 600 barrels of new 7.7 lb_m/gallon 80:20 OWR diesel OBM was used to displace the WBM. The mud was checked after two circulations, and the initial HTHP fluid loss was 15 mL. There was water in the filtrate indicating the emulsion was not stable. The HTHP additive was added for a concentration of 1.5 lb_m/bbl. The OBM began to stabilize with no water in the filtrate. The HTHP additive concentration was increased to 2.0 lb_m/bbl resulting in an HTHP fluid loss of 6.6 mL. As the solids began to accumulate and the electrical stability increased, the fluid loss decreased to 4.2 mL. As requested by the operator, the HTHP fluid loss was maintained <5 mL which required a concentration of 2.2 to 2.3 lb_m/bbl of HTHP additive. Over the duration of the well, the electrical stability decreased slightly, and subsequently a slight increase in the fluid loss was observed but remained less than 5 mL.

Conclusions

- Although laboratory data had indicated adding large concentrations of the HTHP additive in a short amount of time would lower yield point and gel strengths it was not observed in the field trials.
- Additions of the HTHP additive resulted in an ES increase and improved stability.
- The HTHP filter cakes were thin (1-2/32 inch), tough and slick.
- LGS were controlled efficiently.
- Company Man and Driller noted: “It seems to help on drag. We pulled 30-40K less off bottom than we normally do.”
- The Company Man also said, “The excess drag seemed to be non-existent while tripping out of the hole and laying down drill pipe.”
- The HTHP additive achieved superior fluid loss control at much lower dosages in the field trials compared to the uintaite and the styrene based copolymer that had been used previously.

It has been shown that Drill-Sure™ OBM Additive, a novel oil based drilling fluid additive, significantly reduces HTHP fluid loss and enhances emulsion stability. Laboratory tests using diesel, mineral oil and synthetic invert emulsion drilling fluids have shown significant reductions in HTHP fluid loss at concentrations of 6 lb_m/bbl or less. Field trials had similar reductions in HTHP fluid loss at concentrations of 1.5 – 2.5 lb_m/bbl. Both lab tests and field trials confirmed increased emulsion stability. Field trials showed decreased torque and drag when pulling off the bottom and tripping out of the hole.

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Nomenclature

AHR = *After Hot Roll*
API = *American Petroleum Institute*
BHR = *Before Hot Roll*
bbl = *barrel*
cPs = *centipoise*
°C = *degrees Centigrade*
°F = *degrees Fahrenheit*
ECD = *Equivalent Circulating Density*

ES = *Electrical Stability*
HTHP = *High Temperature High Pressure*
K = *Thousands*
KOP = *Kick Off Point*
kpa = *kilopascals*
LGS = *Low Gravity Solids*
lb = *pound*
lb_f = *Pounds force*
lb_m = *Pounds mass*
m = *minute*
MD = *Measured Depth*
mL = *Milliliters*
MW = *Mud Weight*
OBM = *Oil Based Mud*
OWR = *Oil Water Ratio*
psi = *Pounds force per square inch*
PV = *Plastic Viscosity*
ROP = *Rate of Penetration*
RPM = *Revolutions per minute*
s = *seconds*
TD = *Total Depth*
WBM = *Water Based Mud*
YP = *Yield Point*

References

1. Registered trademark of American Gilsonite Company Corporation Oklahoma.