

An Effective Multi-Functional Nanoparticle Drilling Additive for Invert Emulsion Fluid to Drill to Target Depth in a Critical Well

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Abstract

Nowadays critical wells are more frequent due complexity of the target formations and different drilling challenges. In terms of drilling fluids, traditionally Invert Emulsion Fluids (IEF) have been more effective than water-based mud to drill those critical wells, they produce a lower coefficient of friction (CoF) between the drill string and the formation, tighter fluid loss properties and thinner filter wall cake.

A field test in a critical well with expected high torque low ROP and wellbore stability concerns was performed using an effective multi-functional patented Nanoparticle technology in an IEF. The well was successfully drilled with a minimal concentration of 1% v/v of the Nanoparticle drilling additive and after analyzing the real time and field data, it showed that a reduction in torque of more the 42% was achieved and the rate of penetration (ROP) while drilling was increased by 25%. In addition, the oil on cuttings decreased from 12% to 7%, resulting in 41.6% reduction, the High-Pressure High temperature (HPHT) fluid loss values decreased by 75% and this all occurred without any negative effect in the rest of IEF properties.

This successful field application proved the concept of this innovate Nanoparticle IEF technology to overcome torque and weight transmission challenges and reduce both fluid loss and oil on cuttings especially in critical drilling applications, in addition to the subsequent benefits that can be obtained such as nonproductive time reduction.

Introduction

During the angle build-up section in a critical well, based on the difficulty of the target formations high torque, low penetration rate and wellbore instability are frequently expected. Those challenges if are not properly addressed, regularly translate to non-productive time which directly impacts the economic potential of a well. The main type pf drilling fluids used in the oil industry are water-based and oil-based. Both types exhibit benefits to overcome drilling challenges while drilling oil & gas wells.

The selection of the customized or fit for purpose drilling fluids will depend on several factors such as target formation mineralogy composition, expected problems and environmental

regulations. Habitually IEF's offered additional benefits when compared to water-based drilling fluids, such as: show higher stability, increased resistance to contaminants, lower filtration rates, thinner filter cake and higher lubricity. In this paper we will describe how after extensive lab testing and evaluations, a multi-functional Nanoparticle drilling fluids additive for IEF was effective in drilling a critical section in a challenging well.

Experimental Evaluation

Compatibility with Customized Invert Emulsion Fluid

IEF formulations with diesel and low toxicity mineral oil were mixed and evaluated in the lab with different weighting agents prior to the field trial execution. Different concentrations of the IEF Nanoparticle additive were utilized to come up with a suitable concentration to overcome the expected challenges as reduce torque and enhance the fluid loss filtration properties at 320 °F. API Recommended Practices 13B-2 were utilized to perform the following:

- Rheology.
- Electrical Stability.
- High Pressure High Temperature (HPHT) fluid loss.
- Permeable Plugging Test (PPT).

Lab Equipment used:

For the IEF testing in the lab the following equipment's were utilized:

Viscometer:

Utilizing a conventional viscometer, the different rpm readings were taken at 150 F, following API Recommended Practices 13B-2.

HPHT Fluid Loss Test Equipment:

Utilizing a conventional viscometer, the different rpm readings were taken at 150 F, following API Recommended Practices 13B-2.

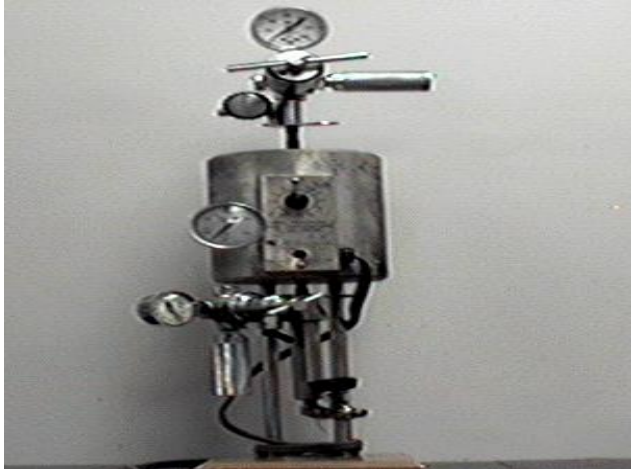


Figure 1 – Conventional HPHT Fluid Loss Test Equipment

Lubricity Tester Equipment:

For the Lubricity testing the temperature was equally 320 F and Torque reduction measured between IEF (control) vs. formulations treated with 1% Nanoparticle Additive.



Figure 2 – Conventional EP Lubricity Tester Equipment

PPT Fluid Loss Test Equipment:

For the PPT testing the temperature was equally 320 F but at 2000 psi differential pressure.

Lab Results

The benefit of Nanoparticle Additive was investigated using fluids formulated with sized calcium carbonate and API Barite. Addition of Nanoparticle Additive (1%), significantly reduced total fluid loss and the water filtrate volumes across the filter paper and Aloxite discs.

There was also a significant reduction in lubricity of IEF low

toxicity mineral oil-based (LTMO) treated with Nanoparticle Additive (1%). The torque reduction was 27.3 in the formulation weighted up with barite and 38.5 in the formulation weighted up with sized calcium carbonate, (Table-1 and Figure 3).

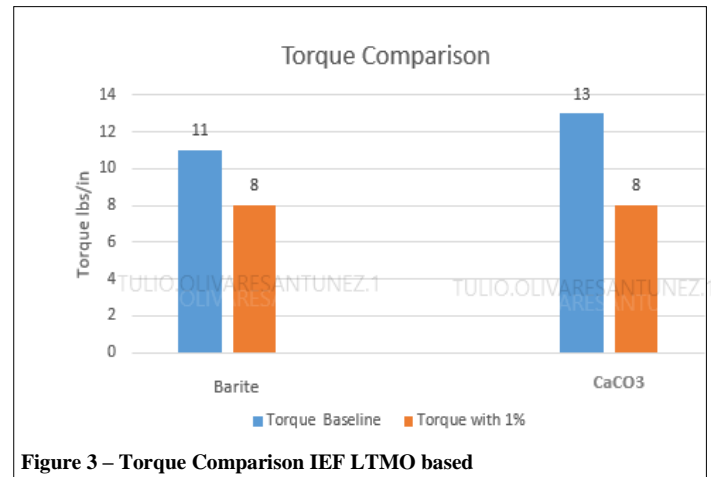


Figure 3 – Torque Comparison IEF LTMO based

Nanoparticle Additive colloidal particles (20% v/v) are suspended in base oil. Reduction in mud rheology and electrical stability improvement is attributed to the additional oil volume introduced when colloidal particles of Nanoparticle Additive were formulated with the control fluids.

An additional lab verification test was performed with an IEF diesel-based sample from the field (Table-2). Diesel based field IEF exhibited a tight fluid loss due to high concentrations of fluid loss additives and colloidal drilled solids already present. Addition of 0.7% of Nanoparticle Additive improved HTHP, PPT fluid loss and lubricity of the field mud.

Nanoparticle Additive was compatible with diesel-based IEF and improves field mud properties high concentration of fluid loss and colloidal drilled solids.

Field Evaluation

A critical build-up section was identified to drill across limestone, shale and sandstone formations. The main challenges for this section were high torque, hole instability, risk of stuck pipe and potential lost circulation. The proposed drilling fluid was a customized IEF. To properly evaluate the Nanoparticle drilling fluid additive, several key performance indicators (KPI) were established before the field implementation. The KPI's were the following:

- Maximum 1% v/v Nanoparticle Additive should maintain a HPHT filtrate loss of less than 4 ml @ 500 psi and 320 F in an IEF.
- Nanoparticle Additive should exhibit no negative effects on IEF properties
- A minimum torque reduction of 20% should be observed after the treatment depending on the solid content in fluid formulation.
- Any value added to rate of penetration.
- Any added value to the oil on cuttings reduction.
- Field trial should be performed in a safe manner.

The initial 100 feet of the selected build-up section was drilled without the nanoparticle additive to establish a baseline. A torque baseline was recorded before the Nanoparticle Additive inclusion into IEF, similarly drilling parameters as weight on bit (WOB), revolutions per minute (RPM), flow rate, rate of penetration (ROP) and oil on cuttings were logged for future comparisons.

While drilling the Nanoparticle Additive was mixed in the IEF gradually until reach the 1% v/v concentration established in the evaluation criteria.

After drilled more than 2000 feet in this critical section with and IEF loaded with 1% v/v the Nanoparticle Additive, no negative impact was observed in the IEF, especially in the mud weight, rheology or electrical stability. The HPHT fluid loss at 320 F and 500 psi differential pressure, decreased immediately after the Nanoparticle additions from 16 ml per 30 minutes to 4 ml per 30 minutes for a 75% reduction (Figure 4).

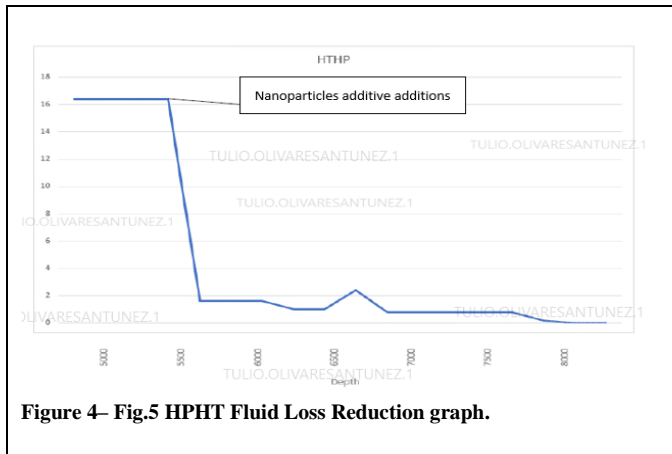


Figure 4– Fig.5 HPHT Fluid Loss Reduction graph.

The torque decreased from 19% after one full circulation with the Nanoparticle Additive to up to 42.85% once the proposed concentration 1% v/v was homogenous in the IEF (Figure 5).

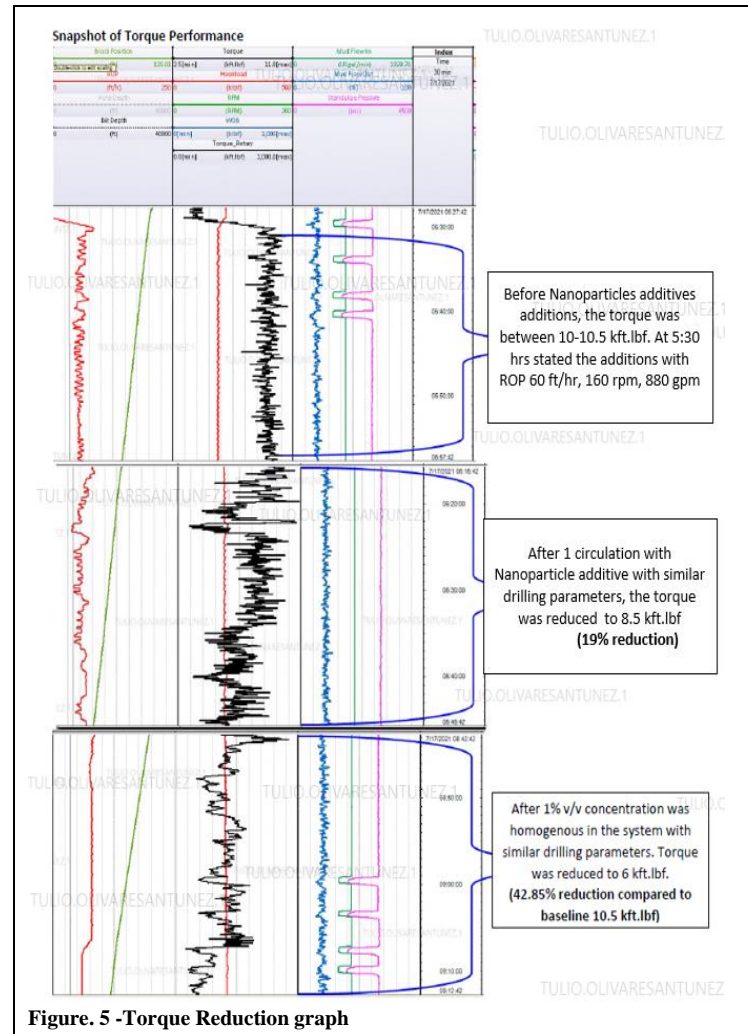


Figure 5 -Torque Reduction graph

Another interesting observation and was not part of the initial evaluation criteria was that oil on cuttings over the shale shakers decreased from 12% to 7% (41.6%) right after the Nanoparticle additions.

Summarizing the KPI in the evaluation criteria and comparing them with the field evaluation results (Table-3).

KPI	Plan	Field Results
Nanoparticle Additive Concentration	No more than 1% v/v	1 % v/v
Effect on IEF	No negative	No negative
HPHT @ 320 F & 500 psi /30 min	< 4 ml	0.8 ml
Torque Reduction	Minimum 20%	42.85%
Oil on Cuttings	Any reduction	41.6% reduction
ROP increase	Any increase	25% increase

Table 3 – KPI vs Field Results Comparisons.

Conclusions

- The torque and HPHT fluid loss values reduction observed in the lab were obtained in the field using a diesel based IEF.
- Up to 42.85% torque reduction was observed with 1% v/v Nanoparticle additions on the field trial with diesel-based IEF.
- The HPHT fluid loss value was significantly reduced in 75% after the 1% v/v Nanoparticle additions.
- No negative effects in the IEF properties were observed after 1% v/v Nanoparticle additions.
- Oil on cuttings over shale shakers decreased 41.6% after 1% v/v Nanoparticle additions.

Base Mud Additive	Mix time	Conc.	Concentration of Nanoparticle Additive			
			0% (Control)	1.0%	0% (Control)	1.0%
Low Toxicity Mineral Oil	-	ml.	233	233	233	233
Primary Emulsifier	2 min.	ppb	12	12	12	12
Secondary emulsifier	2 min	ppb	6	6	6	6
Organophilic Clay	15 min.	ppb	12	12	12	12
CaCl ₂ Brine (25 wt.%)	10 min	ml	82	82	82	82
LIME	5 min.	ppb	7	7	7	7
Barite	30 min.	ppb	100	100	-	-
Sized Calcium Carbonate	30 min.	ppb	-	-	100	100
Nanoparticle Additive	10 min.	ppb	-	22.5	-	22.5
Fluid properties after hot rolling @320F/16 hr.						
Viscometer Reading		°F	150	150	150	150
600 rpm			34	31	33	30
300 rpm			20	18	21	19
200 rpm			16	13	18	15
100 rpm			11	9	13	11
6 rpm			5	4	6	5
3 rpm			4	3	5	4
Gel (10 sec.)		Lb/100ft ²	5	4	6	5
Gel (10 min.)		Lb/100ft ²	6	5	7	6
PV		cP	14	13	12	11
YP		Lb/100ft ²	6	5	9	8
Electrical Stability		mv	399	444	467	473
Lubricity –Torque measured		Lb/inch	11	8	13	8
% Torque reduction			27.3		38.5	
HTHP Total Fluid loss & volume of water in Filtrate @320 °F/500 psi (filter paper);	ml / 30 min.		44 / 6.8	9.0 / 0.5	46 / 6.0	15.8 / 0.8
PPT Total F/L & volume of water in filtrate (@ 320 °F/ 2000 psi, 55 -micron Aloxite Disc	ml/ 30 min.		98 / 24	34 / 6	-	-
PPT Total F/L & volume of water in filtrate (@ 320 °F/ 2000 psi, 10 micron Aloxite Disc			-	-	67 / 16	14.0 / 0

Table – 1 Fluid properties of calcium carbonate and barite IEF (control) vs. formulations treated with Nanoparticle Additive (1%).

Fluid properties of Field IEF before and after treatment with Nanoparticle Additive			
	Unit	Before	After
Concentration of Nanoparticle Additive	% v/v	0	0.7
Mud Weight	pcf	87	85
Oil Retort (Diesel)	%	65	68
Water Retort	%	18	17
Solid Retort	%	17	16
Diesel Water Ratio		78:22	80:20
Low Gravity Solids	%	1.98	2.70
High Gravity Solids	%	12.6	12.50
Viscometer Reading	°F	150	150
600 rpm		109	99
300 rpm		64	57
200 rpm		47	41
100 rpm		30	27
6 rpm		8	6
3 rpm		6	5
Gel (10 sec.)	Lb/100ft ²	9	7
Gel (10 min.)	Lb/100ft ²	14	10
PV	cP	45	42
YP	Lb/100ft ²	19	15
Electrical Stability	mv	600	625
Lubricity –Torque measured	Lb/inch	9	7
% Torque reduction		-	22
HTHP F/L @320 °F/500 psi (filter paper); Total fluid loss & volume of water in Filtrate	ml / 30 min.	3.6/0.6	2.2/0.2
PPT Total F/L & volume of water in filtrate (@ 340 °F/ 2000 psi, 55-micron Aloxite Disc	ml/ 30 min.	9.2/1.6	7.5/0.6

Table – 2 Properties of field IEF (78/22 Diesel/Water ratio) treated with Nanoparticle Additive (0.7% v/v)