

A Flat-Rheology Invert Emulsion System Resulted in Operational Excellence and Nonproductive Time Reduction

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Abstract

When high mud volumes are needed to support the development of the existing fields, logistical and technical constraints make drilling operations challenging and complex. Requirement for customized drilling fluids in curve sections to maintain wellbore stability across unstable shales, reducing the differential stuck tendency of formations, downhole losses, drilling long extended reach sections, and complex completion designs are just a few examples of the technical challenges faced while drilling.

To overcome challenges associated with these applications, a flat rheology invert emulsion system was introduced, and customized for the application after numerous lab tests and optimization. This system uses new technology emulsifier and rheology modifier for achieving flat rheology independent of temperature and pressure changes.

Successful trials and a considerable number of applications resulted in lower pump pressures due to superior equivalent circulating density (ECD) management, and a lower chemical footprint due to lower treatment needed; and the operator was able to drill both curved and reservoir sections using one type of drilling fluid and calcium carbonate as a weighting material. This was a significant improvement from using two separate systems, barite and calcium carbonate weighted, which put too much constraint on logistics.

Significant reduction in downhole losses, hole instability, and stuck pipe incidents were also seen after applying the flat rheology invert emulsion system.

This paper will present a comprehensive overview of novel technology, the steps taken from planning to execution, the overall performance-based results, the effectiveness of the new solution, and the challenges during implementation. The troubleshooting steps taken are also discussed for all the

challenges that occurred while drilling.

Introduction

To maximize the production, horizontal wells through the reservoir having relatively high pore pressures are drilled and completed using stiff openhole screens assembly. Higher pore and rock collapse pressure require a high mud weight nondamaging reservoir drilling fluid to stabilize the wellbore. Many challenges, i.e., very high solids content, accompanied with higher rheology, higher equivalent circulating densities (ECDs), pressure-induced losses, wellbore ballooning, weight material sagging, breaking circulation pressure, and excessive swabbing and surging pressures while tripping in and out are faced during these applications.

In past operational issues such as packing-off, induced mud losses, ballooning, differential sticking, and low cuttings carrying capacity were normally experienced in some areas while drilling with conventional nonaqueous fluids (NAF), resulting in expensive sidetracks and failing in wells delivery. These conventional NAF systems also lack solids tolerance once the mud weights reach beyond 90 lb./ft³ (12 lb./gal) while using calcium carbonate.

After many tests, a flat rheology oil-based system (FROBS) formulation was designed to be the most economical and technically competent option. The FROBS was fine-tuned to meet the required rheological profile at different temperatures. The solids tolerance of the FROBS system was also evaluated in the lab after contaminating the fluid with 10% drill solids while having around 300-330 ppb calcium carbonate as weighting agent. The interactions between the rheology modifier, drill solids, and emulsifier were minimal, and the system maintained its rheological flatness.

What is Flat Rheology Drilling Fluid?

Base oils used to formulate NAFs are chemically inert, but their kinetic viscosity (KV) will decrease with the increasing temperatures (J. Friedheim et al., 2011). The drilling fluid properties (i.e., yield point (YP), 6 and 3 rpm readings, and gels) will also be affected by downhole temperatures. Usually, the viscosity of a conventional system is inversely proportional to temperature (temperature-thinning effect); it reduces when temperature increases and vice versa (**Fig. 1**).

The flat rheology system is different from standard invert systems in the following areas: The emulsifier, wetting agent, and rheology modifiers are different from those typically used in non-flat standard invert systems and provide unique flat rheological properties. The new emulsifier/wetting agent package has a greater solids tolerance when compared to the conventional surfactant package. In this system, the content of organophilic clay has also been significantly reduced using a combination of high-performance clays. This combination of clays and the new surfactant package results in a flat rheology system that delivers better management of ECDs.

The critical properties used to evaluate the system performance are the YP, the 6 rpm reading, and the 10 min gel strength over the application temperature range. A 10 min gel should be less than 1.5 times the 10 second gel, and a 30 min gel should be very close to a 10 min gel to have a flat gel structure for a lower break circulation pressure. FROBS fluids quickly develop a fragile gel strength structure to reduce cuttings slip velocities when the pumps are off and prevent weight material sag, especially in deviated and extended reach wellbores. Fig. 2 shows the rheology profile of the FROBS vs. temperature.

Preparation and Execution

The essential components of FROBS are the primary emulsifier, wetting agent, filtration control agents, and rheology modifiers. More detailed descriptions with the concentrations are given (**Table 1**)

Mud parameters were monitored closely during the drilling phase (**Fig. 4**), any deviations from KPIs were communicated to the operator, and an action plan was implemented immediately. A reporting template to measure the flatness of the system was generated and monitored (**Fig. 3**); monitoring permeability plugging test values was an essential factor in ensuring a firm-thin impermeable filter was developed downhole to mitigate against differential sticking tendencies and seepage losses. A tracking sheet was designed to track value with photos of the filter cake (**Fig. 5**).

To monitor barite sag control, drilling fluid was regularly tested in the field using a viscometer sag test (VST), and fluid samples were sent as needed to perform the shoe sag and static aging tests in the base lab. Since the barite-free FROBS has a

very stable rheological profile irrespective of the downhole temperature fluctuations, it has been proven in the field too that it provides better sag control than the conventional OBM system.

Nonproductive time reduction Summary

Below is a comparison of the performance of the FROBS with the standard NAF system (conventional OBM) in three challenging areas (areas A, B, and C) in different hole sections (12¼, 8½, and 6⅞).

Due to the better thermal stability of the system, the FROBS needed less treatment to maintain the parameters compared to a conventional OBM system. At the same time, In the field, a robust mechanism of pilot testing was developed to determine the exact treatment required to bring the fluid within specs, which helped reduce any potential overtreatment. This resulted in 72% less use of chemicals reducing the drilling fluid cost and transportation cost resulting in lower CO2 emission. Lesser pallets on the rig site also allowed the client to utilize the space to have other essential equipment onboard, improving operational efficiency.

Looking at the nonproductive time, the use of FROBS resulted in an 81% reduction in downhole losses and a 69% reduction in hole instability incidents due to better downhole pressure management derived from the flat rheology profile. A 78% improvement in the stuck pipe incidents was observed in these three fields while drilling using FORBS.

Tables

Typical Flat Rheology High Weight Barite-Free OBM Formulation	
Product	Concentration (lb./bbl.)
Base Fluid	85/15-90/10
Organophilic Clays	4-6
Lime	4-6
Emulsifier	8-12
Wetting Agent	2-3
CaCl ₂ Brine	As Required for water-phase salinity (250 K mg/l)
Polymeric Fluid Loss Control Agent	2-4
Rheology Modifier	0.75-1.5
Calcium Carbonate fine sized	>330

Table 1. A typical FROBS formulation

Figures

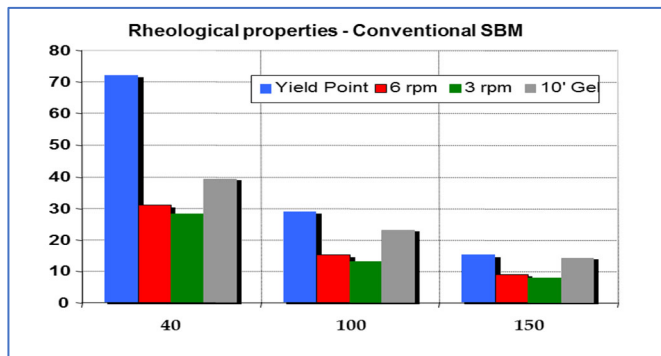


Fig. 1 – Rheological properties of conventional invert drilling fluid vs. temperature.

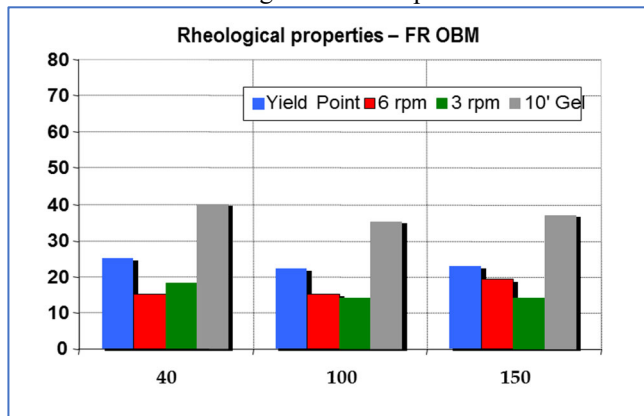


Fig. 2 – Rheological properties FROBS vs. temperature.

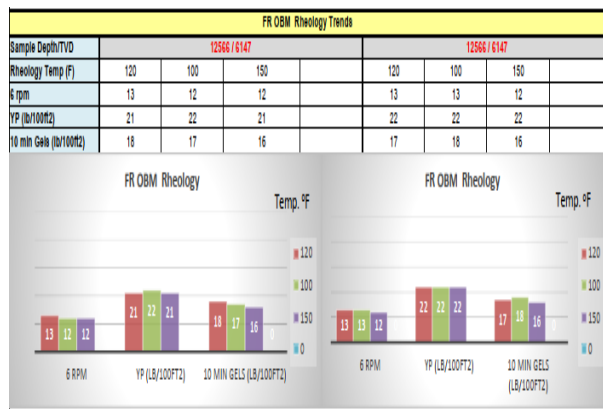


Fig. 3 – FROBS rheology reporting template

MUD PROPERTIES		
Sample From	Active @ 22:00	Active @ 07:00
FlowLine Temp	°F	
Depth/TVD	ft	11474 / 6613
Mud Weight /Temp	lb/ft³ @ °F	97 @ 110
Funnel Viscosity	sec/qt	83
Rheology Temp	°F	150
R600VR300		108 / 64
R200VR100		48 / 29
R6/R3		8 / 7
PV	cP	44
YP	lb/100ft²	20
LSYP	lb/100ft²	6.00
10s/10m/30m Gel		9 / 14 / 17
API Fluid Loss	cc/30min	
HTHP Fluid Loss	cc/30min	2.4@250
Cake API/HTHP	1/32"	7.1
Unc Ret Solids	%vol	34
Correct Solids	%vol	32.64
Oil	%vol	54.00
Uncorr Water	%vol	12
Oil/Water Ratio		82/18
Alkal Mud (Ppm)		3.5
Cl-Whole Mud	mg/L	33000
WPS	mg/L	246981
Lime	lb/bbl	4.53
Emul Stability	volt	720
PPT differential pressure	psi	1500
PPT disc micron size		55
PPT fluid loss 5 min		0.4
PPT total		3.2
PPT operating temp	°F	250

Fig. 4 – Rheology properties in reservoir section

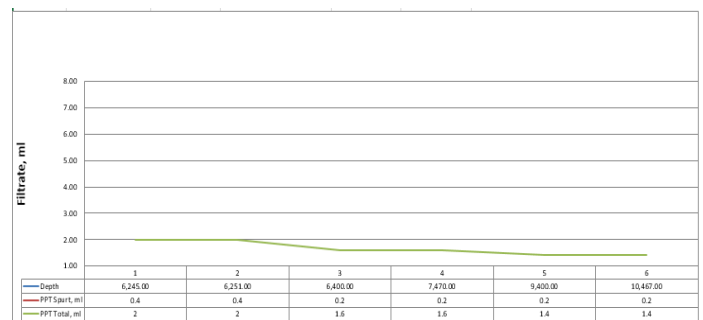


Fig. 5 – PPT and filter cake tracking in the reservoir section

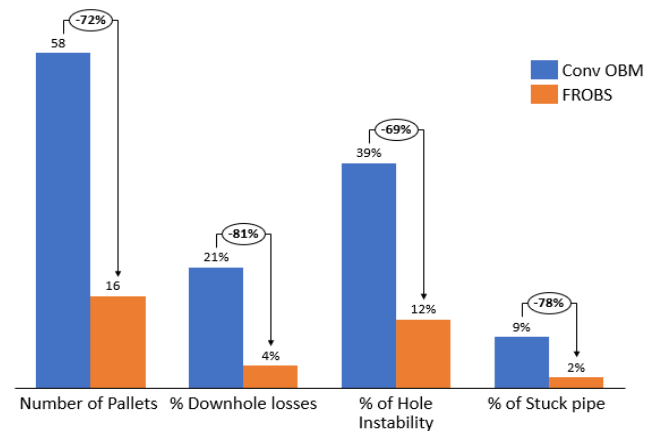


Fig. 6 – Logistic and NPT improvement by FROBS

Conclusions

Meticulous planning and precise execution in the field of the FROBS resulted in significant nonproductive time (NPT) reduction and allowed the operator to achieve many operational milestones. FROBS also reduced CO₂ emissions with less logistical requirements due to lower chemical uses and lesser waste generation. This was a new sustainable technology solution that can be replicated at other locations to have a cost-effective and environmentally friendly alternative to current nonaqueous solutions.

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Nomenclature

FROBS = Flat Rheology Oil-Based System

OBM = Oil Base Mud

ECD= Equivalent Circulating Density

NAF= Nonaqueous Fluids

KV= Kinetic Viscosity

YP= Yield Point

VST= Viscometer Sag Test

PPT= Permeability Plugging Test

NPT= Nonproductive Time

References

1. J. Friedheim, J. Lee, S. Young and D. Cullum, 2011. "New Thermally Independent Rheology Invert Drilling Fluid for Multiple Applications," OMC-2011-085, OMC Ravenna, Italy, March 23-25, 2011

	Conv OBM	FROBS	Conv OBM	FROBS	Conv OBM	FROBS	Conv OBM	FROBS
Field - Section	Number of pallets	Number of pallets	% of Losses	% of Losses	% of Hole Instability	% of Hole Instability	% of Stuck pipe	% of Stuck pipe
A- 12.25"	85.8	22	47%	0%	65%	50%	12	0
A- 8.5"	60.8	13	22%	0%	56%	0%	11	0
A- 6 1/8"	70.9	12	0	0	0%	10%	0	5
B- 12.25"	72	9	33%	0%	67%	0%	17	0
B- 8.5"	45.1	12	33%	5%	33%	5%	0	2.5
B- 6 1/8"	27.9	16	0%	2%	0%	6%	0	4
C- 12.25"	67.8	19	20%	10%	100%	20%	17	2.5
C- 8.5"	44.1	17	30%	4%	30%	8%	20	2
C- 6 1/8"	50.2	20	0%	13%	0%	5%	0	2
Average of whole fields	58	16	21%	4%	39%	12%	9%	2%
Benefits	72% chemicals utilization reduction		81% losses reduction		69% reduction hole instability		78% stuck pipe reduction	
	Less chemicals required		Less losses		Less hole Instability		Less stuck pipe incidents	