Computational Research Progress in Applied Science & Engineering

ISSN 2423-4591

CRPASE Vol. 06(01), 25-29, March 2020

Development and Performance Appraisal of a New Flat Rheology Drilling Fluid System for Drilling Deep Water HPHT Reservoir

Mamidi Lokesh Teja[a*], P. K. Mahata[b]

[a] *Department of Petroleum Engineering and Petrochemical Engineering, University College of Engineering(A), Jawaharlal Nehru Technological University Kakinada , AP, India*

[b] *EOA & HPHT Asset, Oil and Natural Gas Corporation Ltd, Kakinada, AP, India*

Keywords

Deep water,
High Pressure High Temperature,
Flat Rheology,
Equivalent Circulating Density (ECD),
Barite sag.

Abstract

Drilling fluid performs many functions in a drilling process, including the removal of cuttings, lubricating and cooling the drill bits, providing the stability of the hole and preventing the inflow-outflow of fluids between the borehole and the formation. Conventional drilling fluids experience a number of deteriorations such as gelation, degradation of weighting materials and breakdown of polymeric additives under HPHT conditions. Flat rheology profile minimizes adverse effects on ECD, lost circulation, barite sag and hole cleaning activity. This paper highlights the performance of flat rheology drilling fluid systems and their rheology modifiers with special emphasis on water-based mud systems in deep water HPHT reservoirs. Various rheological parameters are experimentally evaluated and the results indicate the constant rheological profile over a wide range of temperatures and pressures. On the basis of the study following drilling fluid system is recommended: New Nanomaterials, KCl-Glycol, low-solids, non-dispersed (LSND) polymer systems(Poly Styrene-co-Butadiene), Glycol-polymer, and Mixture of barite and Manganese Tetra Oxide, TiO2 Nanofluids, Polyol based drilling Fluid system in Water-Based drilling fluid system to provide stable rheology and fluid loss for designing an HPHT tolerant Water-Based mud with an eco-friendly formulation. The newly engineered drilling fluid system exhibits constant flat rheology even in a deepwater environment, has demonstrated promising performance characteristics in field trail.

1. Introduction

There are three distinct classifications of drilling fluids; Water Base Mud (WBM), Oil-based Mud (OBM) and Pneumatic fluid. However, these drilling fluids can further be sub-classified into various other categories. Many criteria are considered for the selection of type of drilling fluid to be used for particular wellbore construction. However, three key factors usually determine the type of fluid selected for a specific well: cost, technical performance and environmental impact [1].

Technical performance of the drilling fluid include cooling and lubricating the bit, carrying cuttings to surface to keep the hole clean, and to counterbalance the overburden pressure to prevent wellbore collapse [2]. Because of a narrow safe-density window in deepwater formation, the high ECD will cause the loss of drilling fluid, thus severely affecting deepwater drilling operations and significantly increasing the cost of drilling fluid [3]. Additional properties in the development of the fluids for deepwater conditions are:

- Stability to extreme temperature ranges, from 34°F to 500°F
- Minimal impact upon equivalent circulating densities (ECD)
- Relatively non-reactive with shales and clays
- The ability to suspend cuttings and keep barite from settling (sag)
- Exhibiting a flat rheological profile over a given range

To meet the above-mentioned properties and fluctuation in rheological properties, many innovative techniques have been developed and applied in the field. Flat Rheology drill fluid system is found immune to these detrimental effects. It means that a relatively stable yield point as well as 10-min gel and 6 r/min reading (Ø6) of the drilling fluid in the deepwater wellbore are maintained in a wide temperature range [4]. Therefore, the ECD of drilling fluid can be effectively controlled, and the loss of drilling fluid can be

* Corresponding Author:
E-mail address: lokeshteja9063@gmail.com– Tel, (+91) 8639291197

Received: 12 January 2020; Accepted: 26 March 2020

reduced. Flat-rheology drilling fluid provides a robust system that is unusually solids tolerant; resistant to cement contamination; remain controllable and stable with seawater intrusion; and experience minimal disposal losses due to contaminants [5]. Less dilution is required, and the system can be reused across several wells. The Comparison of mud rheology for conventional and flat rheology drilling fluid system is shown in Figure 1.

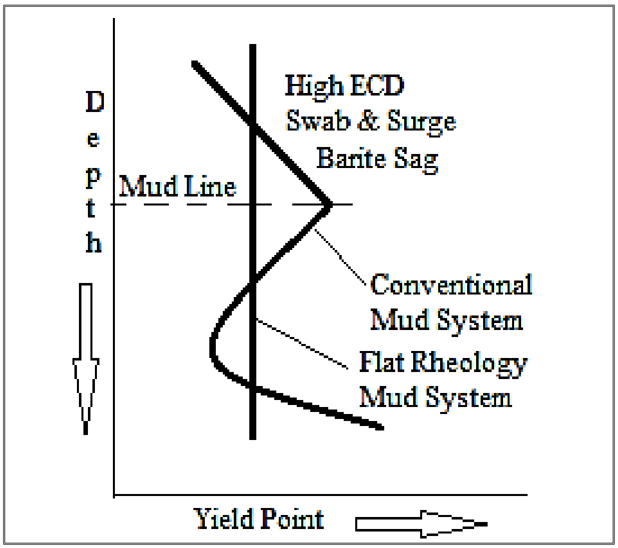

Figure 1. Mud Rheology for Conventional and Flat Rheology Mud System

This paper highlights the performance of various flat rheology drilling fluid systems and their rheology modifiers with special emphasis on water-based mud systems in deep water HPHT reservoirs. Various rheological parameters are experimentally evaluated and the results indicate the constant rheological profile over a wide range of temperatures and pressures. Graphical representation of the rheological profile was made for better understanding. On the basis of the study certain recommendations were made on rheology modifiers that are successful to meet environmental compliance as well as to cope up with hostile wellbore environment during deepwater HPHT reservoir drilling.

2. Design & Development

In the preliminary design phase of this new system certain criteria were set forth to proceed in a systematic fashion to accomplish both the desired environmental and performance goals of the project.

- Exhibited temperature/pressure independent rheological properties focusing primarily on yield point (YP) and gel strengths.
- Attained fluid performance/properties for good hole cleaning and minimal barite sag.

With these design criteria, ester-based fluids were ruled out due to performance limitations (particularly at temperatures >250ºF when ester hydrolysis may occur), toxicity under certain conditions and cost. Both an olefinic external phase and a calcium chloride internal phase were maintained due to overall utility, cost and compliance status [6]. This left all the other components such as emulsifiers, wetting agents, viscosifiers, rheology modifiers, fluid loss additives, and thinners open for re-design or development. Components in this system are specifically developed to attain the goals set out above. It was noted that increasing the total amount of organophilic clay also increased the dependence that rheology had on temperature. Unfortunately, absence of organophilic clay leads to severe barite sag and settling[7].

Despite these certain rheological additives were identified but a major concern is that these constituents must work in concert with the other components. After performing various tests to evaluate various combinations, a new generation of flat rheology drilling fluid system with temperature and pressure independent rheological characteristics was developed. It was also successful to achieve environmental compliance.

3. Experimentation

3.1. Materials and Methods

Materials used in this study are including: Versamul, Lime, LVT-200, Versacoat, Calcium Chloride, Versa Trol, Versa Mod, MI–Bar, Versagel.

Once the base mud formulation was developed a according to the compositions as shown in Table.1 the fluid system was evaluated further in the laboratory to determine its rheological profile. The rheological tests were conducted using a chandler 7600 HPHT viscometer at variable speed (3–600 rpm). A viscometer giving values in cP and by using the formulas known from API recommended practice for field testing drilling fluids. API filtrate and gel 0/10 (3 rpm dial reading after mixing and after 10 min) are determined with using API recommendations (API RP 13B-1, 2003).

Property terms utilized throughout are defined as:

- Plastic Viscosity(PV) = 600 rpm – 300 rpm
  = 72 – 43(from Table 2)
  = 29cp
- Yield Point = 300 rpm – PV
  = 43-29(from Table 2)
  = 14lb/100ft^2

Table 2 collects the rheology data, 600rpm, 300rpm, 200rpm, 6rpm, 3rpm readings and YP, PV 10 min gel, 10 sec gel values in the investigated temperature of 150○F for the formulated mud system. Table 3 indicate the propeties of water based mud that is used in this study.

Table 1. Formulated mud composition

Reagent	Compositions
LVT-200 (bbl)	155.97
Versagel HT (ppb)	5
Lime (ppb)	8
Versamul (ppb)	9
Versacoat HF (ppb)	3
Calcium Chloride (ppb)	22.37
Water (bbl)	63.34
Versa Mod(ppb)	0.25
Versa Trol (ppb)	6
M-I Bar(ppb)	251.91

Table 2. Rheological properties of the designed mud system.

Properties	Value
Mud weight	12.5
OWR	75/25
Rheo Temp(F)	150
600 rpm	76
300 rpm	51
200 rpm	42
100 rpm	31
6 rpm	17
3 rpm	16
PV (cps)	39
YP(lb/100 ft sq.)	26
10 Sec Gel	23
10 Min Gel	33
E.S. (Vts @ 120 F)	718

4. Results and Discussion

Comparisons of Typical Parameters. Figure 2 represents the 600 rpm dail readings at varied temperature from 100ºF to 500ºF for both the conventional WBM and the designed system at 5000psi and 25000psi pressures. Clearly, for the designed system, changes of 600rpm readings were minimal and are quite similar and less than unity under the temperature range. Where as in the conventional WBM, there is a continuous drop for 600rpm with the rise in temperature. It was noted that an average of about 70% to 95% change in 600rpm readings across the temperature range and it reaches near zero at about 350ºF, which shows a notable temperature dependence of rheology. Conceptually, the designed WBM behaves in an expected FR fashion within the temperature range. As for the conventional WBM, lowend rheological properties varied dramatically in the temperature range, suggesting absence of a flat property. These observations will be described further by a detailed comparison of the rheological profiles for the two systems. For a better understanding of flat rhological behaviour of this system graphical illustratation was made in Figures 2 through 3.

Yield Point (YP) is resistance of initial flow of fluid or the stress required in order to move the fluid. It indicates the ability of the drilling mud to carry cuttings to the surface. Moreover, frictional pressure loss is directly related to the YP. It is crutial to maintain the YP of the drillng fluid.

Viscosity Term-Plastic Viscosity (PV) is caused by the mechanical friction within the drilling mud due to interaction between solids, the liquids and the deformation of liquid that is under shear stress.

As the key response, YP and PV usually provides a quantitative insight into the FR profiles of the designed system. Figure 3 illustrates the changes of the PV in the temperature range of 120oF to 440oF for the investigated system. Across the temperature range YP will vary in the range of 28 to 20 lb/100ft2 and PV will vary in the range of 42 to 30 cP for for the designed system. This decline propensity seems much less compared to the conventional mud system. This finding indicates that displays a smaller PV and YP variation relative to conventional water based mud system. On the basis of these conclusions, one could reasonably consider PV and YP to be one FR profile for the mud system under investigation.

10-sec Gel Strength is the shear stress measured at low shear rate after a mud has set quiescently for 10 seconds as per the standard API procedure. Figure 4 shows that the 10-sec gel strength for the the mud system under investigation was higher at low and high pressure. The gel strength for the Water-Based mud reached minimal values (almost zero gel strength) at 250 °F while the Oil Based mud was more tolerate to high temperatures up to 400 °F at which its gel strength sharply dropped.

Table 3. Properties of Water Based Mud used for the study.

Sample From	Active
Time Sample Taken	19:00
Flowing Temp(F)	144
Depth (ft)	10392
TVD (ft)	6250
Mud Weight (ppg)	8.6
Funnel Viscosity(cp)	38
Temp for PV (F)	120
Plastic Viscosity (cp)	5
Yeld Point (lbf/ 100ft sq.)	15
Gel Strength 10 sec (lbf/100ft sq.)	4
Gel Strength 10 min (lbf/100ft sq.)	5
Gel Strength 30 min (lbf/100ft sq.)	6
API Fultrate (ml/30min)	4.6
Cake Thickness API (1/32 in)	0.5
Solid Content (%)	2.5
Oil Content (%)	1
Water Content (%)	96.5
Sand Content (%)	0.1
MBT Capacity (lb/bbl)	0.5
pH	9.2
Mud Alkalanity (Pm) (ml N50 H2SO4)	0.44
Filtrate Alkalanity (Pm) (ml N50 H2SO4)	0.19
Filtrate Alkalanity (Mf) (ml N50 H2SO4)	0.74
Calcium (mg/L)	720
Chlorides (mg/L)	9000
Total Hardness(mg/L)	860
Excess Lime (lb/bbl)	0.01
Potassium (mg/L)	-
Make up Chlorides (mg/L)	7000
Solids adjusted for Salt (%)	1.64
Sulfur Trioxide (ppm)	10

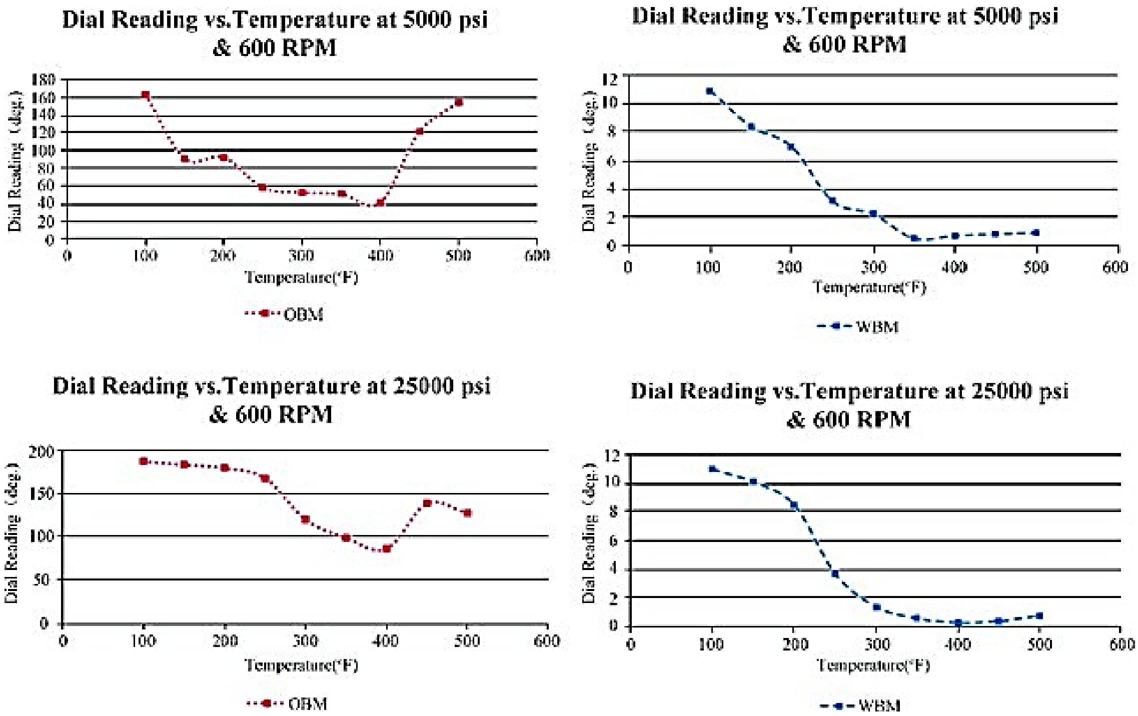

Figure 2. 600rpm Dail Reading vs Temperature at various temperature profile .

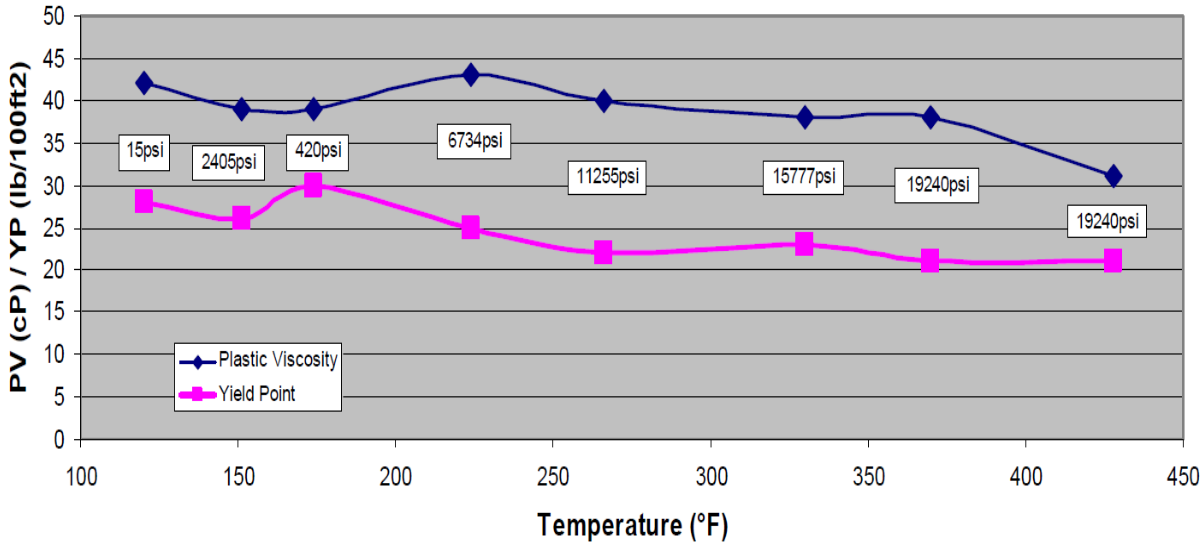

Figure 3. Flat yield point and plastic viscosity profile of formulated mud system.

5. Conclusions

Based on the present investigation a novel drilling fluid system is developed for deepwater drilling operations of varying temperature profiles from 4oC at the bottom of the sea to as high as 205ºC or even higher at the bottom of the hole in HPHT reservoir. Lower temperatures increase the rheology leading to higher Equivalent Circulating density (ECD) and at higher temperatures the rheology is lowered leading to hole cleaning issues. Flat rheology profile minimizes or eliminates such adverse effects on ECD, lost circulation, barite sag and hole cleaning activity. For instance, certain key rheological parameters, such as 6-rpm reading, yield point, and gel strengths remain virtually unchanged when temperature and pressure are varied. The present investigation is a part of the total work program for implementation in the field. Several studies are still in progress for the same including the investigation of flat rheological parameters in water-based drilling fluid.

On the basis of the results obtained from the preliminary studies in-line with the current literature, the following drilling fluid system is recommended: New Nanomaterials, KCl-Glycol, low-solids, non-dispersed (LSND) polymer systems (Poly Styrene-co-Butadiene), Glycol-polymer, and Mixture of barite and Manganese Tetra Oxide, TiO2 Nanofluids, polyol based drilling Fluid system in Water-Based drilling fluid system to provide stable rheology and fluid loss for designing an HPHT tolerant Water-Based mud with an eco-friendly formulation. At varied temperature profiles, it can maintain a stable yield point, 10-min Gel and Ø6 value. Moreover, it showed excellent performance infiltration reduction and shale inhibition, and it can still have good properties even being contaminated by seawater. It was also successful to meet environmental compliance.

Acknowledgements

Views expressed in this paper are of authors only and not necessarily of the organization they belong to. The authors expressed their sincere gratitude to Prof. K. V. Rao, Jawaharlal Nehru Technological University Kakinada for his support, encouragement and guidance throughout the entire course of studies.

References

[1] B. Toups, E. van Oort, J. Lee, New Flat-Rheology Synthetic-Based Mud for Improved Deepwater Drilling SPE, M-I SWACO 2004.

[2] L. Xu, S. Chuan, M.Xu, L. Zhao, Sh.Wen, W. Liu, J. Xu, F. You, Ch. Gong, Jiahua, Experimental Investigations Into the Performance of a Flat-Rheology Water- based Drilling Fluid, Petroleum Engineering College, Yangtze University, Research Center of New Material, China University of Geosciences and Technology Company Limited 2014.

[3] T. Geng, Zh. Qiu, H. Miao, W. Zhang, K. Lei, Performance Evaluation of Synthetic-Based Drilling Fluid with Flat Rheology, School of Petroleum Engineering, China University of Petroleum (East China), Qingdao, China Oilfield Chemicals R&D Institute, COSL, Sanhe, China 2018.

[4] X. Zhao, Zh. Qiu, J. Xu, Ch. Zhao, J. Gao, Flat-rheology oil-based drilling fluid for deepwater drilling School of Petroleum Engineering, China University of Petroleum, Qingdao 266580, China, 2017.

[5] V. Gupta, S. Indulkar, M. Asrani, A. Patel, S. Ramane, A. Sarase, S. Thakur, A. Kumar Singh, An Innovative Rheology Modifier Which Provides Dual Function: Achieves Non-Damaging Clay Free System for Reservoir Drilling and Flat Rheology for Deep Water Drilling, Gumpro Drilling Fluids Pvt. Ltd, 2019.

[6] A. Mullen, Per-Bjarte Tanche-Larsen, David E. Clark, Alan Giles, The Pro's and Con's of Flat Rheology Drilling Fluids Gregory, Baker Hughes Drilling Fluids, 2005.

[7] Mahmood Amani, Mohammed Al-Jubouri, Arash Shadravan, Comparative Study of Using Oil-Based Mud Versus Water-Based Mud in HPHT Fields, Texas A&M University at Qatar, 2012.

[8] Patel et al., Flat Rheology Drilling Fluid, US Patent 7,871,962, 2011.