Modified Nanoclays: An Approach to Stabilizing Drilling Fluids Rheology at High Temperature

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ABSTRACT

Keeping in view the decisiveness of drilling fluids impact on drilling efficiency, this work presents an approach to stabilize the drilling fluid rheology in high temperature and pressure conditions by making use of modified nano-clays. An abundantly available clay in Oman, attapulgite was tested in purified nano-form (0.3 nm diameter) for its effectiveness to tailor the rheology of drilling fluids swiftly, that are able to retain their properties over a wide range of operating temperatures, thus ensuring efficient operation in versatile formations. Sufficient experiments were performed to compare the rheology of drilling fluids containing Bentonite only, which is a common drilling fluid additive, with drilling fluids containing bentonite in presence of small quantities of attapulgite nanoparticles. After successive experiments an absolute proportion of water, bentonite and attapulgite nanoparticles was found out that gives consistent results at various temperatures i.e. stable drilling fluid rheology. The best recorded results are reported in this paper and the properties focused here are the plastic viscosity, gel strength, yield point and density.

Keywords: Drilling Fluids, Bentonite, Rheology, High temperature and Pressure

1 INTRODUCTION

The benefits of improving tools, materials, skills, use of down-hole rotation tools and any other innovation for improving drilling operations is almost ineffectual if they are not used in presence of an accurate drilling fluid.

The drilling fluid circulation has to be maintained throughout the drilling process during which it has to perform certain crucial tasks like: hole cleaning, provide effective lubrication between the bore-hole and drill string, cooling of the bit and maintaining appropriate drilling pressure hence weight on bit, and these functions has to be performed consistently throughout the operation regardless of the type of formation and operating conditions. These functions are purely dependent on the rheological properties of the drilling fluids mainly the viscosity, density and gel strength and lack in performance in any of these functions leads to severe drilling problems like: lost circulation, high torque and drag, instability with changing conditions and stuck pipe events. These problems when stumble upon leads to huge financial losses in the form of calling the need for expensive additives, huge non-productive time in resolving the problem and in worst cases may cause to abandonment of the well. The problems becomes more severe when drilling deep due to the considerable increase in temperature that results in deterioration of fluid properties.

Keeping in view the intricacy in the problem of opting a right drilling fluid formulation, there is a strong need to have a healthier knowledge and a timely control on the rheological properties of the drilling fluid so that the properties may be changed to suit any particular type of drilling environment, and this requires a novel solution that is so accurate and punctual in performing its function that it should influence the rheology when added in very small concentration and promptly.

One major emerging application of nanotechnology in oil reservoir engineering are in the sector of developing new types of smart fluids for improved/enhanced oil recovery, & drilling [1,2]. Due to totally different & highly enhanced physio-mechanical, chemical, electrical, thermal, hydrodynamic properties & interaction potential of nano materials compared to their parent materials the nanos are considered the most promising material of choice for smart fluid design for O&G field application [3].

One of the pioneering work of Paiaman & Duraya [4] presents useful results by using carbon black nano-particles and reported superior drilling fluid properties. The significance of the use of nanoparticles of clay materials in drilling fluids has also reported first time by Abdo and Danish [5-7].

The work presents a novel solution to have unanticipated set of rheological properties by use of combination of regular drilling fluid additive bentonite and nanoparticles synthesized from a locally abundant material in Oman called atapulgite. A schematic procedure for purification and breaking down particles to nano size for uniform dispersion is tested. The significance of reducing the particle size distribution of attapulgite has been highlighted and its impact on rheology is presented when used in nano size particle distribution. It displayed remarkable gel strength characteristics even though whilst maintaining a low viscosity. The shear thinning behavior was also investigated and showed enviable results. The paper is mainly focused on application of attapulgite nanoparticles in drilling fluids, and stabilizing the recipes at high temperature.

2 ATTAPULGITE NANOPARTICLES SYNTHESIS

Locally available attapulgite was collected which is mainly available in form of solid big chunks in mountains and then the attapulgite chunks were crushed in the crusher to obtain coarse particles so that it can be taken for fine milling. Fritsch attrition milling machine was used to mill the coarse grains to obtain fine powder for several hours. After milling for several hours the fine powder was sieved to obtain particles of mesh size ≤ 20 μm. The fine powder of mesh size ≤ 20 μm was carried for further processing. The fine powder is washed thoroughly by distilled water and ethanol after centrifuging to remove all insoluble impurities. High power sonicator was used to impart high frequency ultrasonic vibrations to suspensions of attapulgite fine powder in ethanol. This causes the separation of needle like chains and clusters and further breaking down of the material to smaller size without damaging the morphology. The ethanol environment serves as a chemical shield to protect against flocculation during the sonication process. This occurs due to the formation of a charged layer over the surface of the particles thus repelling each other hence facilitating the dispersion process. The process was carried out at different frequencies of vibration and different no. of hours to find the optimum size range and dispersion. They remain suspended without flocculation and settling to the bottom, due to the fact that at nano-level the surface forces become more dominant than the gravity forces.

3 USE OF ATTAPULGITE IN DRILLING FLUIDS

Bentonite based drilling fluids have the limitation of flocculation and limited functionality at high pressure and pressure conditions. Because of high water absorption capability and swelling characteristics the dispersion behavior of bentonite is non uniform and have huge problem of flocculation which results in insufficient and inconsistent rheology of drilling fluids.

On the other hand, attapulgite has very good colloidal properties such as: specific features in dispersion, high temperature endurance, salt and alkali resistance, and also high adsorbing and de-coloring capabilities.

The special nanorods structure and large specific surface area can endow attapulgite with many unique physical and chemical properties; therefore, attapulgite attracted the interest to be used as efficient and stable rheology modifier for drilling fluids.

4 RESULTS AND DISCUSSION

4.1 Effect of size reduction of attapulgite

Samples of drilling fluids containing 40 gms of attapulgite in different sizes with 500 ml of water were prepared and viscosity measurements carried out by Fann 35 Viscometer. Table-1 shows the effect of different particle size distributions (PSD) of attapulgite on plactic viscosity (PV) and yield point (YP).

		P.V (cp)	**YP**
Sample 1	Fine grinded	2.5	1
Sample 2	Size ≤63 μm	2.5	0.5
Sample 3	Size ≤20 μm	2	1
Sample 4	Size = 30 nm diameter	4	1

Table-1: PV and YP of samples containing different PSD of attapulgite

It can be observed from the results presented in table-1, that the reduction of PSD from sample 1- sample 3 (Micro or greater) does not impart any significant improvement in the plastic viscosity and yield point of the drilling fluid samples and gives almost similar values at different RPMs. For sample-4 (nano-size) the viscosity began to deviate from the trend than what was observed in size reduction from sample 1- sample 3. Figure 1 Shows the uniforml dispersed attapulgite nanoparticles with diameters as small as 30 nm.

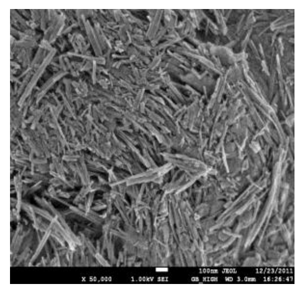

Figure 1: Uniformly dispersed attapulgite nanoparticles

This shows that the functionality of nano sized particles now came into play and thus showed high viscosity. Even though improvement in viscosity is quite obvious but the constant yield point has to be justified by measuring gel strength for scrutinizing the carrying capacity of the fluid. Table-2 presents the 10 sec and 10 min gel strengths and densities measured at 3 rpm for above four samples.

		10 sec	10 min	% Increase	Density (gm/cm³)
1	Fine grinded	0.2	0.3	50	1.015
2	Size ≤63 μm	0.6	0.8	33.4	1.020
3	Size ≤20 μm	0.5	0.65	30	1.030
4	Size = 30 nm diameter	1.5	4.5	200	1.055

Table-2: 10 sec and 10 min gel strengths and densities of samples 1-4

Thus from the gel strength measurements the effectiveness of nano-sized attapulgite clay in terms of its carrying capacity is very well justified. It displayed an improvement of 200% in terms of its gelling characteristics thus confirming its superior performance in holding on the drill cuttings when in static condition. It is convenient to conclude that the problem of poor hole cleaning can be tackled well by this recipe. The high gelling characteristics of the fluids may demand a high starting torque which needs to be justified by investigating the shear thinning behavior of the fluid. In addition to the properties discussed above it is also crucial to keep an eye on the density of the drilling fluid because if formation pressure increases, mud density should also be increased, often with barite (or other weighting materials) to balance pressure and keep the wellbore stable. Thus it is vital to maintain a density suitable enough to fulfill the above mentioned requirements while varying the viscosity, yield point and gel strength. Keeping in view this fact, density tests carried out on the same samples by using mud density balance revealed noteworthy results in the form of displaying significant changes with changing size. It is thus evident that any of the rheological parameters can be tailored by changing the size to suit any type of drilling environment. Density test results are also presented in table-2.

It is evident from the results in table-2, that reducing the particle size has a considerable effect on the mud density.

4.2 Effect of composition of attapulgite

The crystal structure of bentonite is 3-layer sheet and forms particles in form of flakes thus having a medium ranged surface area. Flocculation is one of the major drawbacks of bentonite. Whereas, attapulgite which has a chain like crystal structure forms particles in form of needles thus have a high surface area and hence increased reactivity. Attapulgite forms gel structures in fresh and salt water by establishing a lattice structure of particles connected through hydrogen bonds.

After successive testing it is found that the use of attapulgite alone with reduced PSD imparts superior rheological properties to the samples, but lacks in maintaining high yield point values. Thus based on the fact that bentonite have capability of forming thick drilling fluids (high yield points) it is recommended to use small composition of attapulgite nanoparticles in precence of bentonite. Table 3 and Figure 2 demonstrates the variation in rheological properties with increasing quantity of attapulgite.

Bentonite (gms)	Attapulgite (gms)	Gel Strength (10 min)	Viscosity (cp)	Y.P
40	2	35	10	45
40	4	24	8	16
40	6	21.5	6	13
40	8	17	7	9

Table 3: Change in rheological properties with increasing attapulgite nanoparticles

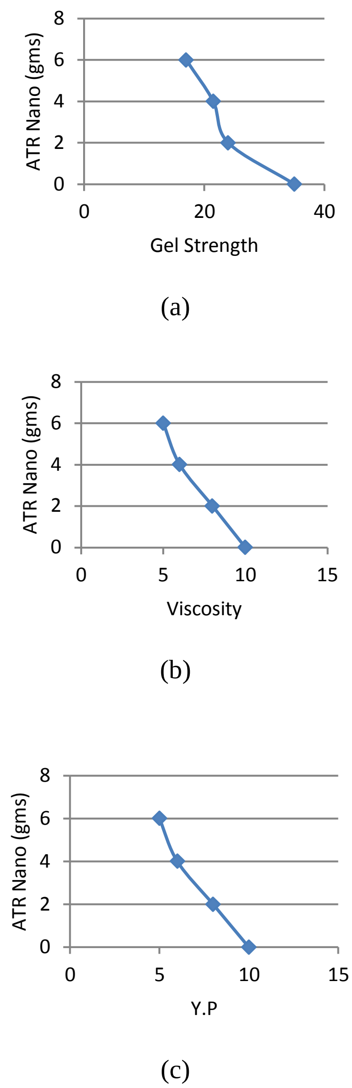

Fig 2: (a) Decrease in Gel strength (b) decrease in viscosity (c) decrease in YP with increasing quantity of attapulgite nanoparticles

4.3 Bentonite at high temperature

In order to compare the stability of attapulgite with bentonite, first bentonite was tested. 45.7 gms of bentonite in572 ml of water was used and the sample tested at different temperatures. Results are shown in table 4.

Temp	**Gel Strength**	**Viscosity**	**Y.P**	**Density**
25	33	14	27	1.47
45	42	11.5	37	1.42
75	59	9	60	1.41
90	65	5	100	1.4

Table 4: Change in rheological properties at varying temperatures (Bentonite)

4.4 Attapulgite at high temperature

After successive trial and errors a recipe containing 5.7 gms of attapulgite in presence of 40 gms bentonite and 572 ml water was found to have stable properties at high temperatures. The results are shown in table 5.

Temp	Gel Strength	Viscosity	Y.P	Density
25	12	7	15	1.4
45	13	7	15	1.39
75	13	6.8	16	1.41
90	14	7	16	1.4

Table 5: Constant rheological properties at varying temperatures (attapulgite)

The recipe containing attapulgite nanoparticles were found to be almost stable at temperatures as high as 90 ^{o}C.

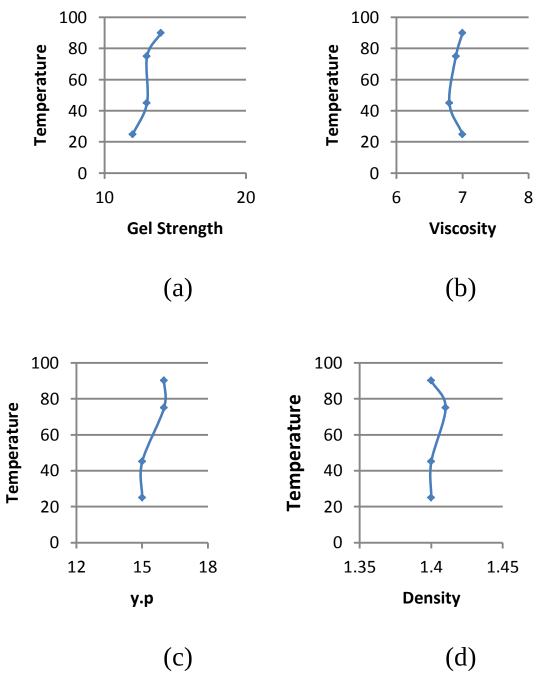

Fig 3: (a) Temp vs gel strength (b) Temp vs viscosity (c) Temp vs YP (d) Temp vs Density

Figure 3 (a-d) shows graphically the trend of properties with changing temperature. It is observed that the properties remain almost constant with changing temperature.

5 CONCLUSION

A new material attapulgite that is abundantly available in Oman was tested for use in drilling fluids as a replacement of regular drilling fluid additive bentonite. The material attapulgite was collected and a schematic procedure was developed to purify and breakdown the particles to nanosize. Significant improvement in rheology was observed when using attapulgite nanoparticles in small additive concentration with bentonite and water. Attapulgite have the capability to tailor the properties of drilling fluids by just reducing the particle size. Thus it can be used as a rheology modifier and eliminates the use of other expensive drilling fluid additives. Attapulgite based drilling fluids provides with balanced and optimized set of rheological properties without calling the need for other additives. Another remarkable feature of attapulgite nanoparticles is their stability at high temperature. Bentonite alone is not found to be stable, while adding small concentration of attapulgite nanoparticles endows the drilling fluid with considerable stablity at high temperature.

REFERENCES

[1] Igor N. Evdokimov, Nikolaj Yu. Eliseev, Aleksandr P. Losev, Mikhail A. Novikov, “Emerging Petroleum-Oriented Nanotechnologies for Reservoir Engineering”, SPE Russian Oil and Gas Technical Conference and Exhibition, 3-6 October 2006, Moscow, Russia, 102060-MS.

[2] S. Bhattacharyya, G. Lelong & M.-L. Saboungi, ‘Recent progress in the synthesis and selected applications of MCM-41: a short review,’ Journal of Experimental Nanoscience Vol. 1, No. 3, 375-395, 2006.

[3] Md. Amanullah, Ashraf M. Al-Tahini, “Nano-Technology–Its Significance in Smart Fluid Development for Oil and Gas Field Application”, SPE Saudi Arabia Section Technical Symposium, 9-11 May 2009, AlKhobar, Saudi Arabia, 126102-MS.

[4] A.M. Paiaman, Bandar Duraya Al-Anazi, “Feasibility of decreasing pipe sticking probability using nanoparticles”, NAFTA,Vol 60 (12), pp. 645-647 (2009).

[5] J. Abdo, M. Tahat, M. Danish, “Nano-Enhanced Drilling fluids: Capable solution for reducing hight torque and drag in drilling operations”, Eighteenth Annual International Conference on composites/nano engineering (ICCE - 18), Anchorage, Alaska,USA, July, 2010

[6] J. Abdo, M. Danish, “Nanoparticles: Promising Solution to Overcome Stern Drilling Problems”, Nanotech Conference and exhibition, Anaheim, California, June, 2010.

[7] J. Abdo and M. Danish Haneef, ‘Nano-Enhanced drilling fluids: Pioneering approach to overcome uncompromising drilling problems’, J. Energy Resources Technology (ASME), Volume 134 (1), pp 501-506, 2012.