An Investigation Into Formation Damage Decreasing By The Promising Solution Of Using Nano-Based Drilling Fluids

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Abstract

Formation damage is one of the productivity decreasing agents which can have many other problems consequently; formation damage may be because of many different reasons that one of them is using unsuitable and undesired drilling fluids, so this paper investigates conventional drilling fluids and the problems that each of them can cause in the formation and borehole, represents a comparison of different properties of common types of drilling fluids including oil-based and water-based versus nano-based type, and evaluates other works in the same field, current investigation and earlier experimental and numerical studies demonstrate the significant benefits of using nano-based drilling fluids in order to reduce formation damage problems caused by drilling fluids and their efficient properties.

Introduction

Once a drill bit enters the pay zone until the well is put on production, a formation is exposed to series of operations and fluids that can impair its productive capacity. This reduction in productivity is termed as formation damage [Issham et al., 2005]. It can be defined as the alteration of producing formation near the wellbore due to the introduction of foreign fluids and the consequent interaction with the fluids and formation [McKinney, 1988]. Previous field and laboratory studies showed that the operations during drilling, completion, workover, production, and stimulation works are potential sources of formation damage [Issham et al., 2005].

During drilling, formation damage attributes primarily from two sources: filtrate invasion from a drilling fluid and the accompanying invasion and migration of solids. The damaging solids may come directly from fluid system or from the formation itself. The intrusion and deposition of these mobile particles lead to the blockage of pore throats, which include a reduction in permeability of the formation [Tovar, J, 1994].

Water or oil-based drilling fluid is the first foreign fluid that contacts the reservoir zone of a borehole and the major cause of damage during drilling is due to the invasion of mud solids. These desirable mud solids can cause severe formation damage in the presence of a poor quality mud cake. Mungun (1965) pointed out that the primary cause of permeability reduction in the invaded zone is the blockage of pore passages by dispersed solid particles. This blockage or barrier may be due to the physical movement of the fine particles into the formation or chemical interactions of solids/filtrate with the formation or a combination of both. The investigation of the effect of particle penetration and particle concentration on formation damage and depth of invasion conducted by Todd et al. (1990) indicates that even 1-15 ppm water suspension containing less than 3 micron size particles may cause in-depth invasion with serious damage to the formation permeability [Md. Amanullah, 2011]. That's why suspended particles, even in very dilute solutions like mud spurt may cause significant permeability impairment and thus may lead to a drastic reduction in oil and gas production. The solids and the liquid phases invading the near wellbore formation may also interact with the formations such as salt, clays, anhydrite, etc leading to precipitation, clay dispersion, pore throat blockage, in-situ polymerization and thus may create a flow barrier to stop or reduce oil and gas flow. [Amanullah and Ziad, 2010].

The fine particles coming into the drilling mud as a part of drill solids may also cause severe formation damage if the mud cake formed on the borehole wall is poorly dispersed, very thick due to particle flocculation and has highly porous fabric due to loose-fabric formation by the flocs, aggregates and the particles. This highlights the importance of mud design to produce crystal clear filtrate with virtually no spurt, low filtrate volume and well dispersed and tightly packed mud cake. As the ultimate aim of drilling is the recovery of oil and gas to the maximum level i.e. more than 70% of the oil and gas in place, the use of a non-damaging drill-in fluid while drilling the reservoir is very important [Md. Amanullah, 2011].

Hence, prevention of formation damage in the first place is the best strategic tool than cleaning the damage in the second place the numerous mechanisms that result in formation damage may be generally classified as to the manner by which they decrease production [Allen, 1993]:

(1) Reduced absolute permeability of formation due to plugging of pore channels by induced particles.
(2) Reduced relative permeability to oil due to an increase in water saturation or oil-wetting rock.
(3) Increased viscosity of reservoir fluid results from emulsions or high-viscosity treating fluids.

The degree of damage varies with parameters such as differential pressure, mud annular velocity, characteristics of the formation as well as the composition of the mud filtrate and solids that flow with it under dynamic conditions [Tovar, J, 1994]. To minimize damage, a mud should have low fluid loss, low fine solid concentration, should form a thin, impermeable mud cake, and exhibit good rheological properties [McKinney, 1988]. Oil-based and synthetic oil-based mud, under most conditions, makes excellent low damage fluids. Indeed this was the reason for their initial development. They possess low spurt loss, which minimize particle invasion, and their oil filtrate does not cause water block and does not mobilize water sensitive clays. As discussed above, an excess of surfactant in the filtrate can cause changes in wettability and oil mud should be used with caution, particularly in dry gas reservoirs. Good bridging is also essential when drilling a reservoir with an oil mud as the loss of whole mud, including the water phase, deep into a reservoir could cause emulsion blocking [McNaughton, 1982].

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The common formation damage mechanisms are incompatibility of fluids, incompatibility of rock and fluid, fines migration and blocking of phases, adsorption, wettability alteration, bacteria activity, etc [Dr. Mikhailov N. , 2010].

The main factors affecting formation damage are particle and pore size distribution, fines mobilization and retention forces, flow rate, salt concentrations, pore pressure, temperature, presence of organic materials, rock and particles wettability, capillary pressure [Liu and Civan, 1995].

The present work investigates drilling fluid role in formation damage, and nano-based drilling fluid as a type of drilling mud which helps decreasing formation damage problems.

DRILLING FLUIDS

A drilling mud is a complex fluid which comprises of multitude of additives. The type and amount of additives is based on the drilling method employed and the type of reservoir to be drilled. The drilling mud can be broadly classified as water based mud (WBM), oil based mud (OBM), synthetic based mud (SBM), emulsions, invert emulsions, air, foam fluids, etc.

Water based muds (WBM): These consist of water/brine as the base fluid. As they are environment friendly, the drill cuttings can be disposed of easily [Subhash N. et al, 2010]. Further advancements/research in WBM would be to combine the advantages of both the VES and bio-polymers to obtain a suitable blend which can outweigh the disadvantages of both VES and bio-polymers [Ogugbue et al, 2010].

Limitations of WBDF Major Limitations of WBDF include (Mellot, 2008), include:

1) The ability of WBDF to dissolve salts which may result in unwanted increase in density.
2) The ability of WBDF to interfere with the flow of oil and gas through porous medium.
3) The ability of WBDF to promote the disintegration and dispersion of clays.
4) The inability of WBDF to drill through water sensitive **shale** or "heaving shale".
5) The ability of WBDF to corrode iron such as drill pipes, drill collars and drill bits.

Strengths of WBDF:

1) It is cheap and hence cost effective.
2) It is environmentally friendly at some extent.
3) It is easily accessible and abundantly available.
4) Faster ROP.

Remedies to Limitations of WBDF: The most important remedy to make-up for the limitations of WBDF is to use OBDF. According to Dye et al., (2006), unlike WBDFs, OBDFs do not dissolve salts because they are non-polar. They do not interfere with the contents of the reservoir and the porous media because the base oil (no.2 diesel) is native to the reservoir. They do not promote clay disintegration and hence can be used to drill through heaving shale because they are unreactive. They are lubricants hence do not corrode pipes, collars and drill bits.

Oil based muds (OBM): They comprise of oil as the base fluid. The fluid formulation is complex compared to WBM and is expensive. Their advantages include excellent fluid loss control, no shale swelling, adequate lubrication to drill bits, good cutting carrying ability etc. Their disadvantages include poor bonding between the cement and formation due to oil wet surfaces; poor filter cake clean up and possible environmental hazards, like seepage into aquifers and causing pollution, etc [Subhash N. et al, 2010]. Recently, Issham et al. [Issham Ismail et al., 2005] presented data showing the highly unsuitability of OBMs in formation damage, for sandstone reservoirs.

Limitations of OBDF:

1) It is very expensive.
2) Disposal of cuttings resulting from the use of OBDF is very expensive.
3) Treatment of cuttings prior to disposal is also very expensive.
4) OBDF are not environmentally friendly because their disposal may result in the pollution of lands, contamination of water bearing aquifers, and the decimation of the coral reefs.
5) Lower ROP compared with WBDF.
6) They may cause changes in wettability, (Chen et al., 2004).
7) Unsuitable for use in dry gas reservoirs.

Strenghts of OBDF:

1) It provides a means for avoiding all the limitations of the WBDF.

2) It provides better lubrication.
3) It has higher boiling points.
4) It has also a lower freezing point.

Remedies to Limitations of OBDF: No doubt, the OBDF is the better comparing with WBDF in terms of performance and OBDF is the most widely used drilling fluid. However, it has a major limitation, not environmentally friendly. Hence, the solution to this shortcoming is the development of environmentally friendly drilling fluids that will be cheaper and hence cost effective.

Gas Based Drilling Fuid (GBDF*):* GBDF is also known as Reduced- Pressure Drilling Fluid. Gas based drilling fluid can be classified into: (1) dry gas, (2) mist (in which droplets of water or mud are carried in the air stream, (3) foam (in which air bubbles are surrounded by a film of water containing a foam stabilizing-agent, and (4) gel foam (in which the foam contains film-strengthening agents, such as organic polymer or bentonite). The most common gas drilling fluid is air, although, natural gas (methane) exhaust, or combustion gases are sometimes used.

Early development of GBDF: Gas was first injected in September 1932 (Foran, 1934) in the Big Lake Field, Texas to flush formation water out of the productive zone. Earlier in the 1920s, pressure drilling with a control head, which allows control of gas and oil flow while drilling the productive zone had been used in Mexico. Around this time in Oklahoma, gas at a volume ratio of 143:1 metered into the circulating water was used for drilling and it was observed that productivity was greatly improved compared to that of oil wells drilled with mud. Similarly, in Carlifornia, gas-injection practices were used to drill subnormal –pressure sands (Grinsfelder and Law, 1938). Around the 1950s, rigs carrying out seismic exploration in parts of Canada shot-holes using compressed air due to water scarcity of extremely low temperatures (Shallenberger, 1953). In 1951, El Pao Natural Gas Co. began drilling with gas to avoid loss circulation. They also observed that ROP and Footage per bit increased greatly, productivity was much higher, and well clean-up was facilitated (Hollis, 1953). As the method was continuously tried in different areas, both practical limitations and advantages were recognized.

Current trend in the Formulation of GBDF:
Most of the technological improvements seen in the drilling of well with air have come from the mining industry which is primarily associated with shallow large bore wells. The oil and gas industry has failed to make the same technological advancement in air drilling as compared to wells drilled with liquid or mud systems (Mellot, 2008).
However, the followings are some of the current trends in the use of air for drilling:

Aerate drilling fluids: Aerate drilling fluids are generally used in underbalanced drilling and where there is no contact with reservoir hydrocarbons or water. The advantages of air drilling process include high rate of penetration, no solid contamination, no formation damage, no lost circulation etc. This results in less number of trips in and out of the wellbore and makes the process economical.
Future challenges would include a thorough understanding of the physics involved in the wellbore hydraulics and to increase the safety factor for the successful execution of this process [Kenneth et al., 2007].

Foam fluids: Foam fluids are used in underbalanced and deep water and ultra-deep water drilling where the operating pressure window is very narrow. A slight increase in mud density will cause micro/macro fractures and a slight decrease in mud density will cause fluid influx into the wellbore due to high pore pressure. Thus, a better control over the equivalent circulating density (ECD) is needed. Foam fluids generally comprise of 5-25% liquid phase and 75-95% gaseous phase. The liquid phase could be fresh water or brines. The gaseous phase is usually an inert gas. A surfactant is used as a stabilizer and it comprises about 5% of the fluid system. The fluid system can be weighted up using heavy brines or barites. It has superior cuttings carrying ability compared to air drilling fluids.
There are two types of foam drilling fluids: (1) a stable foam which is a regular foam fluid system with water or brines as a continuous phase and

gas as a dispersing phase, and (2) a stiff foam consisting of viscosified water or brine as a continuous phase and gas as a dispersed phase [Subhash N. et al, 2010].

Gel Foam and Stiff Foam: Basically, this is the use of a slurry prepared consisting of (by weight) 98% water; 0.3%soda ash; 3.5%bentonite; 0.17% guar gum; and 1% volume of a suitable commercially available foaming agent. In recent formulations, guar gum has been substituted by other polymers and bentonite by other clays (Crews, 1964).

Limitations of GBDF:
1) It cannot be used to drill through water bearing zones. When water-bearing formations are drilled using air, the wetted cuttings will stick together and will not be carried from the hole by the air stream.
2) Gas may be corrosive.
3) High risk of explosion.

Strengths of GBDF:
1) Reduction of the pressure gradient of the drilling fluid to less than that exerted by a column of water.
2) Risk of formation damage is minimized when using GBDF.
3) Faster drilling rate in hard rock areas.
4) It is abundantly available and cheap.
5) Minimization of loss circulation.
6) Improved bit performance.
7) Ready detection of hydrocarbon.

Remedies to Limitations of GBDF: Wetting and balling of cuttings can be reduced by introducing zinc or calcium stearate into the air stream. Having gas detectors on the rig floor will reduce the risk of explosion due to leakage.

Invert emulsion muds (IEM): It consists of oil/synthetic hydrocarbon as the external phase and water/brine as the internal phase and the fluid stability is achieved by adding a surfactant. Their advantages include generation of a thin filter cake, increased hole stability, increased rate of penetration, insensitiveness towards shales etc. They are not biodegradable and drilling mud becomes unstable at high temperature and pressure. The latest development in invert emulsion drilling mud is the negative alkalinity invert emulsion drilling mud [Patel, 1999]. It comprises of synthetic esters as external phase and water/brine as the internal phase. They have low intrinsic viscosity and rapid bio-degradability. They are resistant to contamination by sea water cement slurry and are highly stable under high temperature and pressure. They are made from readily available fatty acid esters and hence they are relatively inexpensive and environmentally friendly [Subhash N. et al, 2010].

Nano Enhanced (Nano-Based) Drilling Fluid (NEDF): Drilling, drill-in or completion fluids that contain at least one additive with particle size in the range of 1-100 nanometers are defined as nano-based drilling, drill-in and completion fluids. Physically a nano sized particle has a\ dimension that is one billionth of a meter. Typical human hair has a diameter of about 80,000 nanometers and one nanometer is roughly equal to the width of 10 hydrogen atoms [Saeid et al. 2006] if measured using an atomic scale.

DISCUSSION:

Compared to the macro and micro-sized materials, nano sized materials have drastically higher surface area to volume ratio (Fig. 1), [Amanullah & Al-Tahini, 2009].

The extremely high surface area to volume ratio of nano-materials compared to the macro and micro materials of the same mother source provides them dramatically increased interaction potentials with reactive shale to eliminate shale-drilling mud interactions and the associated borehole problems. The capability of nanomaterials to form well dispersed plastering effect on the borehole wall with concentration of less than 1% in a drilling mud system is expected to improve the fluid and drilling performance significantly; the extremely high surface area to volume ratio of nanoparticles (see Figure 1) can provide several other technical benefits for safe and economic drilling operation. As for example, the huge surface area to volume ratio of nano-based mud additive is expected to improve the thermal conductivity of nano-based fluids. Hence, the enhanced thermal conductivity of drilling mud will provide efficient cooling of drill bit leading to a significant increase in operating life cycle of a drill bit. The high heat transfer coefficient of nano-containing fluid will also play a positive role in cooling the drilling mud quickly at the surface [Md. Amanullah, 2011].

Nano-Silica, nano-graphene, and other nano-based materials have been proposed for use as alternative mud additives. A nano-material based mud system is defined as that mud containing at least one additive with particle size in the range of 1-100 nanometers [Amanullah et al., 2009]. It is based on the number of nano-sized additives in the mud system; mud systems can be classified as simple nano-mud system or advanced nano-mud system. Nano-materials in mud systems are expected to reduce the total solids and/or chemical content of such mud systems and hence reducing the overall cost of mud system development.

It is known that presence of ordinary materials in drill mud can cause increased viscosity and mud weight [Jerry J. Rayborl et al., 1992]. This high mud weight can cause damage to sub-surface formations, plugging of production zones, hole erosion, decreased penetration rate, pipe failures, stuck pipe and lost circulation [Ford et al., 1990, Amoco, 1996, BHI, 1998, Reid et al., 2000 and Njobuenwu and Nna, 2005].

In order to decrease probability of formation damage we have to use new materials in which do not increase viscosity and mud weight very much. Because as mentioned before, this increases in viscosity and mud weight may lead to some problems that the most important one is formation damage.

Using nanoparticles in drilling mud that causes several changes in mud properties can partly help to solve many problems. For example in an experimental study by Jerry J. Rayborl et al. we can see the different properties of carbon black nanoparticles and their role in making drilling mud properties better to use and decreasing formation damage problems due to its suitable properties (table 1 and 2).

Another important property that can effect formation damage due to drilling mud is the particle size, which affect the mud cake permeability (low permeability), as an example particle size of carbon black nanoparticles are presented in table 3, which briefly specific gravity of carbon black is typically 1.9 - 2.1 [Dr. Jawad K.Oleiwi et al., 2011] and, estimated initial diameter of carbon black particles is about 30 nanometers in which after aggregation this value will be about 150 to 500 nanometers [Abouzar Mirzaei Paiaman et al. 2008].

Recently **Bai Xiaodong and Pu Xiaolin** (2010) in an investigation on using organic nano-latex and inorganic particles as bridging and block agents along with the polymer additives, evaluated layer efficiency, temperature resistance, inhibitive ability, pollution resistance and sedimentation stability of the organic/inorganic composite nanometer water-based mud system. The investigation indicates their mud system has higher isolation layer efficiency with zero filtration loss after 120 min. It is effective up to 180 ˚C. The system has strong shale inhibitive ability with swell rate of 17.92% and the recovery rate of 95%. It has strong salt and bit cuttings resistance up to 15%NaCl, 7% $CaCl_2$ and 15% bit cuttings. At last, the sedimentation stability of the system is good and meets requirements of in-situ drilling operations.

Drilling fluids should exhibit a gel structure with apparent yield stress to prevent suspended solids such as hole-cuttings and barite particles from settling, should flow be stopped for any reason. However, the gel structure should disintegrate quickly once flow is restarted. In other words, a drilling fluid should have a high viscosity at low shear rates to keep solids in suspension, but a low viscosity at high shear rates. Such behavior is obtained by adding polymeric additives and clay particles that form a long-range, three-dimensional network that breaks down on applying a shear stress, but quickly rebuilds when flow ceases, which consequently decreases formation damage due to suspended solids penetration [Sushant Agarwal, 2011].

Invert emulsions were prepared with nanoclay and nanosilica as emulsion stabilizers. It was found that though both nanoclay and nanosilica could stabilize the emulsions, the nanosilica was more effective and had a large effect on the droplet size. In addition, the most stable emulsion was obtained when both nanoclay and nanosilica were used in combination. Figure 2 shows flow curves for invert emulsions prepared with nanoclay and nanosilica. It can be seen that the largest increase in the yield stress and viscosity is obtained when nanoclay and nanosilica are used together. This kind of effect also is observed in the morphology of the emulsions [Sushant Agarwal, 2011].

From the experimental work by **Amanullah and Tan** (2001) and **Amanullah** (2002) it was shown that the absence of the deposition of loose, thick, poorly packed particles in the mudcakes deposited by nano-based fluids is a major factor in reducing the filtrate and spurt loss potential of the muds. Hence, it can be concluded that the well dispersed, tight and the very thin mudcake deposited by nano-based drilling and drill-in fluids can play an important role in preventing drilling and formation damage problems.

The comparison of the rheological profiles and the gel strength behavior of the nano-based fluids A, B and C (3 types of nano-based fluids which were prepared by **Md. Amanullah, 2011**) with the commonly used micro-sized bentonite-based mud indicates far superior viscous and gelling properties (see Figures 3 and 4) for the nano-based fluid systems and thus expected to provide better fluid performance while drilling. The difference between the 600 rpm and 300 rpm readings of the bentonite mud and the nano-based fluids indicate superior yield point for all the nano-based fluid. The higher yield point of the nano-based fluids will ensure better dynamic suspension of drilling cuttings and efficient cleaning of the borehole while drilling. The flat type gel strength property of the nano-based drilling fluid (see Figure 4) compared to the progressive type gel strength of the micro-sized bentonite-based drilling mud also demonstrate superior functional behavior of nano-based fluid while drilling. The development of adequate gel strength of the nano-based fluid immediately after cession of the drilling operation will allow homogeneous and distributed suspension of the cuttings within the fluid column without causing any concentrated accumulation of drill cuttings in critical borehole areas. This will eliminates problems such as hole pack-off, bridging, cuttings bed formation in deviated, horizontal and extended reach wells, sagging in deviated borehole, mechanical pipe sticking, etc.

There is a high possibility of formation of embedded cuttings beds at the low sides of horizontal wells due to the presence of a poor quality mudcake. The ability of nano-based fluids to deposit a very thin and tightly packed mudcake on the borehole wall demonstrate its potential in eliminating or reducing the scope of embedded cuttings bed formation in deviated, horizontal and extended reach wells. This may lead to effective cleaning of deviated, horizontal and extended reach boreholes by the hydrodynamic action of circulating drilling mud. Solids content of drilling mud is one of the factors that increases formation damage, reduces productivity index and decreases ROP. In the formulation of any muds, some solids are intentionally added to fulfill the functional tasks of the mud.

As the solids content of the mud has a direct effect on the ROP and also on the formation damage potential of the mud, it is advisable to use the amount of desirable solids as little as possible. Due to huge surface area to volume ratio (see Figure 1), and requirement of a tiny concentration (< 1% w/w) of nanomaterials (see Figure 6) in the fluid formulation, nano-based drilling fluid can play an important role to increase the rate of penetration. It may be mentioned that higher is the amount of desirable and total solids in the drilling mud lower is the rate of penetration. Due to ultra-low concentration of desirable solids content in unweighted nano based fluids compared to unweighted conventional fluid (see Figure 6), the unweighted nano-based fluid could be an ideal candidate to drill competent hard rock formations to enhance the rate of penetration.

The comparison of the API fluid loss behavior of the nano-based fluids shown in Figure 5 with respect to the micro-sized bentonite mud shows similar API fluid loss behavior but without any spurt loss. In contrast to the nano-based fluid, the bentonite mud shows about 2 cc spurt loss in API test conditions. The lack of spurt loss of the nano-based fluids demonstrates an interesting feature of the fluids. Mud spurt is one of the major factors that create serious damage to the producing zone. The particulate materials that are carried by the mud spurt cause blockage to the pores and pore throats and thus lead to the formation of an internal mud cake as a roughly circular ring in the invaded zone of the borehole. This circular ring of packed solids is tightly fixed in the rock matrix and the narrow pore throats of the near wellbore producing zone and thus often difficult to clean by the back flow of hydrocarbon during testing and production. Due to the intimate association of the solid particles borne by the mud spurt into the near wellbore rock matrix, the treatment fluid that is used to clean the mud cake before cementing and completing a well often performs very badly. In most of the cases, the best treatment fluids used by the industry fail to clean the borehole properly to restore the original poro-perm characteristics of the invaded zone [Md. Amanullah, 2011].

TABLES AND FIGURES:

Table1
effect of nanoparticles on reduction of mud cake thickness [Jerry J. Rayborl et al., 1992]

Pressure & Temperature	Initial mud cake thickness	Adding 2% by volume of carbon black to mud	Percentage of improvement
100 psi, 80 F	32/4	32/3	25 %
500 psi, 300 F	32/11	32/8	27 %

Table2
effect of nanoparticles on reduction of mud viscosity and yield point [Jerry J. Rayborl et al., 1992]

Cases of experiment	Initial mud at 100 F	Adding 2 % by volume of carbon black to mud	Initial mud at 275 F	Adding 2 % by volume of carbon black to mud
Plastic viscosity, cp	32	26	38	23
Yield point, 100 lb/sq ft	7	5	10	3

Table3
Average size of carbon black particles [Jerry J. Rayborl et al., 1992]

Stages of forming carbon black	Initial particles	Initial aggregates
Estimated diameter	30 nanometers	150-500 nanometers

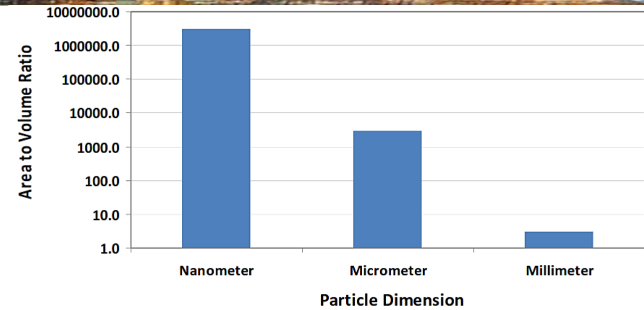

Figure 1
Surface Area to Volume Ratio of Same Volume of Materials
(After Amanullah & Al-Tahini, 2009)

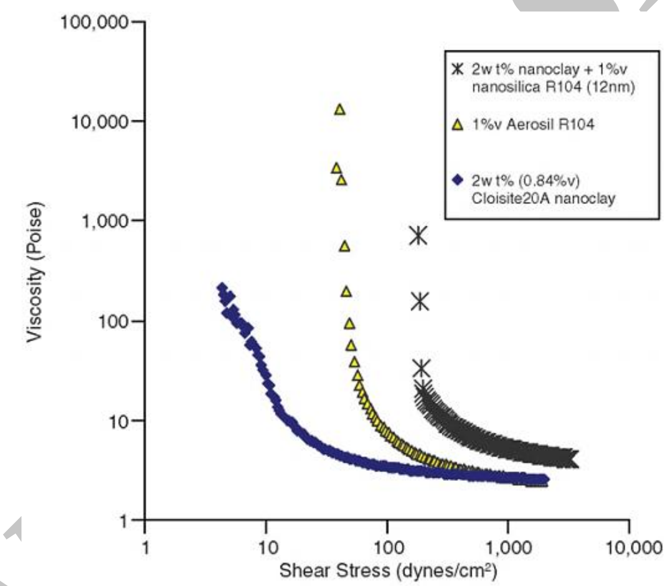

Figure 2
Effect of Nanoclay and Nanosilica on Flow Behavior of Invert Emulsions (30 percent water by volume)
[Sushant Agarwal, 2011]

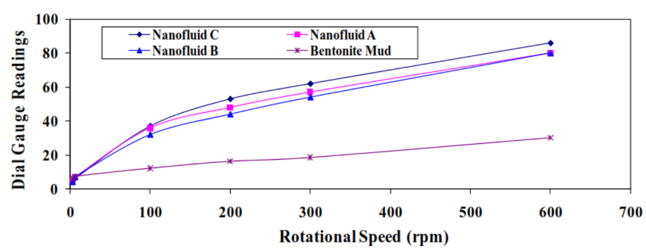

Figure 3
Comparison of Rheological Profile of Bentonite-based and Nano-based fluids
[Md. Amanullah, 2011]

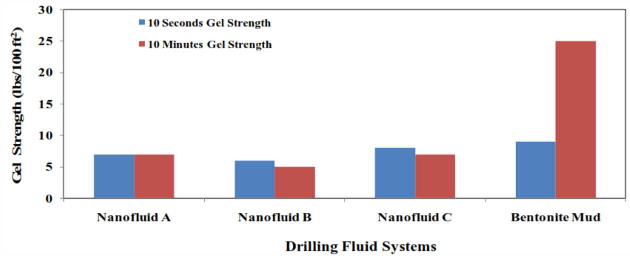

Figure 4
Comparison of Gel strength of Bentonite-based and Nano-based fluids
[Md. Amanullah, 2011]

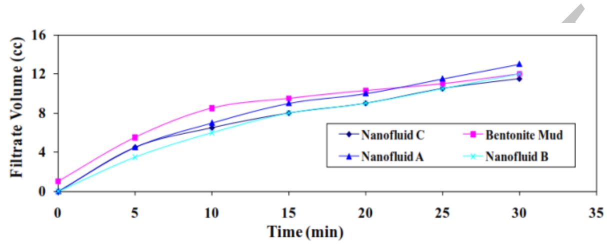

Figure 5
Comparison of API fluid loss of Bentonite-based and Nano-based fluids
[Md. Amanullah, 2011]

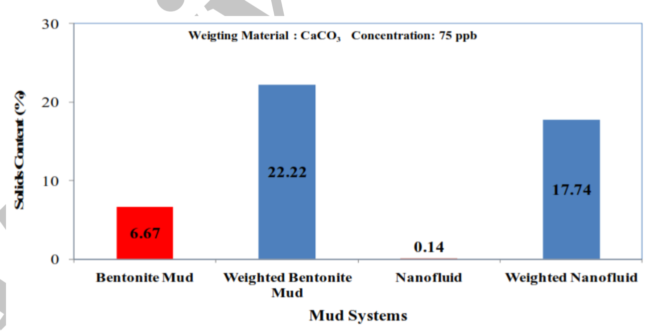

Figure 6
Comparison of solids content of Bentonite-based and Nano-based fluids
[Md. Amanullah, 2011]

CONCLUSIONS

Recent research has demonstrated that WBDF, OBDF, are not suitable in the most cases and can cause many damages in the formation, and with the advent of nano-technology, it is well known that Nano-fluids have attractive properties as in higher heat conductivity which helps mud cooling, formation consolidation, wettability alteration, less spurt loss, thin mudcake film, less solid penetration, good and desirable cutting exhaustion, etc.

Nano-based drilling fluid form nano-induced composites and aggregates that is helpful in circulation loss control, the exclusion of an internal mudcake by nano-based fluids increases the capability and ease of borehole cleaning, the deposited extremely thin mudcake of nano-based fluids decreases the differential pipe sticking in highly permeable formations dramatically, another benefit that is necessary to mention is extremely low solid contents which can highly help to decrease formation damage due to pore blockage via solids penetration. Further studies are required to identify new substances and compositions to decrease formation damage problem which are due to drilling mud properties, fortunately nano-technology extension is really a valuable way reaching this goal.

KEYWORDS:
Drilling fluid, formation damage, Nano-based, rheology, oil-based, water-based

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