

Substituting Locally Sourced Carbon Nano Particle with the Conventional Additives



Ekeinde, Evelyn Bose¹, Okujagu, Diepiriye C², Dosunmu Adewale³

^{1,3}Department of Petroleum and Gas Engineering, Federal University Otuoke Federal University Otuoke Bayelsa State, Nigeria

²Centre for Petroleum Geosciences (CPG), University of Port Harcourt University of Port Harcourt Choba Rivers state, Nigeria

ABSTRACT: Nanoparticle drilling fluids have the potential to minimize wellbore instability problems. There is a need for the development of a new generation of drilling fluids to handle wellbore instability problems especially in lost circulation zones and shale problems. A rheological model is needed to accurately describe the rheology of nano base drilling fluid because limited experimental data are currently available for using carbon nano particles in water base mud and inability of current methods to address shale strength with increased open hole time reduction of critical mud weight to prevent hole collapse in challenging environment like depleted formation, narrow margin, HPHT wells. The study attempted to produce nano particles locally where the in-situ formation of floating catalyst was used. It involved the floating of catalyst particles by thermal decomposition of organometallic where argon, acethelene and nitrogen gas were used. The CNP WBM formulation was compared with the conventional base mud. Result Show that the CNP mud gave a better result for the fluid loss which can be used as a fluid loss property in the study mud, CNP gave 6.2mls while soltex gave 8.2mls and also CNP gave a thin and firm filter cake of 0.18cm as compared to the soltex formulated mud. Therefore, CNP is a good fluid loss additive and enhances the rheological properties of mud, also helped to improve and add value to local content in the oil and gas industry and save us the cost through the application of locally sourced drilling fluid and save foreign exchange and It has export potentials in the Gulf of Guinea and other oil provinces

KEYWORDS: CNP, Soltex, Drilling fluid, Water base mud, fluid loss.

INTRODUCTION

There has been a shift in drilling methods from horizontal to rotary in terms of square footage drilled. Drilling to extreme depths is impossible without it. At all times, it's called "drilling mud," and it's there to keep the drill bit in place. There are numerous uses for drilling fluids. Drilling requires a large amount of fluid to ensure that the job is done correctly. Drilling fluids must meet certain standards in order to ensure the safety of the well and a successful completion (Sedaghatzadeh et al., 2012). Conventional macro and micro types of fluid additives often cannot be used for certain important tasks in difficult drilling operations because they lack the right physical, mechanical, chemical, thermal, and environmental properties.

To put it another way, the chemical and polymer industries are on the lookout for environmentally friendly, biodegradable, and chemically stable products. Oil and gas exploration and extraction can benefit greatly from the use of smart fluids made from these materials. Nanomaterials are thought to be the best material for designing smart fluids in oil and gas field applications. Because of their many unique properties, nanomaterials can interact with a wide variety of other materials and are therefore distinct from their parent materials (Amanullah, Sedaghatzadeh et al., 2011). Because of their high surface-to-volume ratio, nanoparticles have a large amount of surface area. As a result, they're able to engage with the world around them. Thus, fewer nanoparticles are required for each application, resulting in cost savings. People in the drilling engineering field believe nanotechnology could be a big help in solving some of the most common issues they face. Most of the nanoparticles used in drilling fluids are intended to enhance the fluid's rheological properties, such as lubricity and gel strength. This demonstrates the importance of using high-quality ingredients when making mud.

Mud systems can benefit from the addition of nanoparticles to improve lubrication and reduce the likelihood of drill string jams during drilling (Sedaghatzadeh et al., 2012). The stuck pipe's recovery could be greatly aided by the nano-based fluid. Drilling mud containing nanomaterials could theoretically reduce the stickiness of mud cakes by depositing a thin nano-adhesive nanofilm on the drill string's surface. To prevent the drill pipe from sticking, this would be beneficial. It's estimated that drilling mud exposure

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to shale results in billions of dollars in lost revenue each year (or mud invasion in shale). Nanoparticle drilling fluids could reduce the risk of wellbore instability. Using nano-fluids can reduce the amount of exposure that shales have to drilling mud, which can cause them to swell and make it difficult for the wellbore to remain in place. An unstable wellbore can be avoided by using this method. Friction between the drill string and the hole wall exacerbates torque and drag issues when drilling with a long reach. In order to reduce torque and drag on the drill bit, various types of drilling muds have been developed. Nanofluids can significantly reduce frictional resistance between the pipe and the borehole wall because nanomaterials can form very small and very thin films. This is because the ability of nanomaterials to form extremely small and thin films causes a thin lubricating film to form at the pipe-wall interface (Nabhani and Emami, 2012). In comparison to their volume, nanoparticles have a large surface area, which makes it easier for them to interact with the mud and matrix that surrounds them. These bonding sites could be used to form bonds with functional groups, influencing chain entanglement and thus creating distinct matrix properties from this surface area, as a result (Abdul Razak et al., 2014).

As the world's demand for oil and natural gas grows, deep well exploration is becoming increasingly important. Drilling fluids lose their rheological properties under high pressure and temperature, according to research. Both deepwater drilling and offshore operations are affected by this (Abdul Razak et al., 2014). A number of variables influence the efficiency with which an oil or gas well can be dug. It becomes increasingly difficult to select drilling fluid and its additives over time, as more products with different functions are introduced to the market. Additives and heat transfer properties are essential for a drilling fluid to perform well.

Nano-Based Drilling Fluid

A new type of nano-based drilling fluid has been developed that has excellent rheological and filtration properties as well as the ability to produce high-quality mud cakes. When commercial nano-materials were combined with a nano-stabilizer, it was created. Stabilizing formations and cleaning the borehole wall with an ultra-thin, tightly packed, and uniformly dispersed mud cake has been demonstrated in highly permeable formations. This mud cake has also been shown to reduce differential pipe sticking. A nano-based drilling fluid may also help reduce torque and drag during deviated drilling operations like horizontal drilling, as there may be less frictional resistance between a drill pipe and the borehole wall.

Drilling can be safer and more efficient thanks to the high surface area to volume ratio of nanoparticles. Thermal conductivity has been increased, making it easier to cool the drill bit. As a result, the drill bit has a much longer lifespan.

The Fluid Loss Additives

Soltex

Soltex Additive is a water-soluble sodium asphalt sulfonate that has been sulfonated in an unusual way. There are numerous applications for this mud conditioner, ranging from shale formation stabilization to lubricity enhancement. It is possible to use Soltex Additive in combination with other Soltex additives to improve the filter cake properties of both oil and water-based muds. When it comes to making muds that are both water and oil-based look fantastic, Soltex Additive has been around for over 50 years. During the drilling process, a large amount of Soltex Additive is used on both the drilled solids and the well bore itself. One day after the first treatment, increase the amount of Soltex Additive by 50%.

There are a lot of positive aspects to Soltex. Water and oil solubility can be controlled to achieve optimal chemical and physical performance and minimize damage to productive formations. Environmentally friendly, too, because of the reaction it has with shales to slow or halt the process of sloughing and swelling

Carbon Nano Particles

One of the most distinctive features of nanotechnology is the way in which its properties change as the size of the nanomaterials decreases. A number of nanostructured materials, including carbon nanoparticles (CNTs), have received a lot of attention in recent years. Pure carbon is what it's known as a "fullerene." As with graphite, each atom is linked to three other atoms in the same way. When it was first exhibited in the 1970s, the public was largely uninterested in it. In 1991, it was discovered by Iijima, and Smalley synthesized it for the first time (1993). In addition to arc discharge and laser ablation, chemical vapor deposition can also be used to create these components (Rafique & Iqbal, 2011). In accordance with the principles governing the assembly of atoms.

LITERATURE REVIEW

Nanoparticle-rich fluids could improve wellbore stability significantly. Wellbore stability control can be improved by adding specially designed nanoparticles to water-based mud (Sedaghatzadeh et al., 2012). The small particle size of nano-fluid makes it easier to keep shale from swelling and causing instability in the wellbore. Using nano-fluid particles, which are smaller than the shales' pore throat length, a bridge and a plug can be constructed. When Nabhani and Emami collaborated on a paper in 2012, it was part of their research. The use of nanoparticles in water-based drilling fluids has also been examined by Ismail et al. (2014). These materials

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were added to the water-based drilling fluid along with MWCNTs and nanometals like titanium dioxide (TiO₂) and aluminum oxide (AlO₃) (CuO). Increased MWCNT nanoparticle concentration resulted in reduced filtration loss.

It's been a failure to use materials of micro and macro materials to keep circulation going in these areas, according to Abdo and Haneef (2012). Experiments were conducted by Nasser et al. (2013) in order to see how drilling mud nanoparticle performance as nanoparticles. Researchers have discovered that when drilling mud nanoparticles are subjected to greater pressure and temperature, they have better maintenance characteristics. There are claims that nanotechnology can be used to improve the properties of drilling fluids. Because of this, standard drilling mud loses its ability to flow as a result of a decrease in pressure.

Nanoparticles can be used to reduce differential pipe sticking in Iranian oil fields, according to Abouzar et al. (2008). Adding nanoparticles to drilling mud can alter the mud's properties in a variety of ways, according to recent research. Drilling mud was spiked with carbon black nanoparticles for a variety of purposes in this study. The mud cakes aren't as thick as they used to be due to the presence of carbon black particles in the mud. Vikas and Rajat were tasked with finding out how fly ash affected water-based drilling fluids' properties (2013a, 2013b). The filtration properties of fly ash improved as the concentration of fly ash increased, according to the results of the experiments. A smaller cake thickness and lower filter loss were the results of the drilling fluid system's improved ability to bridge together smaller particles.

Using nano-clay and nanosilica to stabilize invert emulsion model drilling fluids for HTHP drilling was studied by Agarwal et al. (2011). A stable emulsion can be maintained by either of the nanomaterials by themselves, but combining them yielded optimal results. It was discovered that the nanoparticles' composition and hydrophobic or hydrophilic nature were critical factors in determining plastic viscosity. Process synthesis and optimization can speed up the creation of carbon nanostructures, according to Iyuke and his colleagues. Carbon nanotubes can be made in two different ways, according to his research (CNTs). The first step is to heat organometallics to create floating catalyst particles. "In-situ formation of floating catalyst particles by the thermal decomposition of organometallics" was used in their research to produce positive outcomes. It was in Nature Communications in 2013 that Ogolo and co-authors explained how nanofluids keep sand particles from moving away from each other. Ogolo et al., (2012) worked on the enhancement of oil recovery using nano particle.

According to Sedaghatzadeh et al., (2012) CNT can be produced as Multi-wall carbon nano-tube (MWCNT). MWCNTs were created through chemical vapour deposition. Hydrophobicity is a common property of MWCNTs, making it difficult for them to disperse in water. Nanotubes with hydrophilic functional groups were created by treating them with acid. MWCNTs were treated with nitric acid to improve their performance (69 percent). One gram of MWCNTs and 40 mL of nitric acid boiled and refluxed for four hours together. In order to remove the acidity, the sample was diluted with deionized water, filtered, and rinsed over and over again until it was completely neutral.

Nanoparticles have been studied by Onyekonwu and Ogolo (2010) to see if they can help with oil recovery. Using polysilicon nanoparticles of three different types (lipophobic, hydrophilic, and hydrophobic NP), they improved oil recovery by 50%. CNTs: Researchers Ghorbani et al. developed a new method of making CNTs, which could withstand being squeezed, in 2014. The rheological and filtration properties of water-based drilling fluids can be studied using nanomaterials. To accomplish this, Salih et al. (2016) used nanomaterials. Adding aluminum oxide, nickel oxide, zirconium oxide, and silica silicon oxide to other nanoparticles can help keep clayey fines from moving and sticking to sand grains, as well as other nanoparticles. It was in Nature Communications in 2013 that Ogolo and co-authors explained how nanofluids keep sand particles from moving away from each other. Ogolo et al., (2012) worked on the enhancement of oil recovery using nano particle.

Sedaghatzadeh and colleagues (2012) found that carbon nanotubes can be transformed into multi-wall carbon nanotubes, according to their findings (MWCNT). MWCNTs were created through chemical vapour deposition. Hydrophobicity is a common property of MWCNTs, making it difficult for them to disperse in water. Nanotubes with hydrophilic functional groups were created by treating them with acid. MWCNTs were treated with nitric acid to improve their performance (69 percent). One gram of MWCNTs and 40 mL of nitric acid boiled and refluxed for four hours together. In order to remove the acidity, the sample was diluted with deionized water, filtered, and rinsed over and over again until it was completely neutral.

Nanoparticles have been studied by Onyekonwu and Ogolo (2010) to see if they can help with oil recovery. In order to increase oil recovery, they applied three different types of polysilicon nanoparticles (hydrophilic, lipophilic, and hydrophobic NP) to rocks. Nanoparticles improved oil recovery, according to the researchers. Carbon Nanotubes were studied in a similar way by Ghorbani et al. (2014). Carbon Nanotubes with Enhanced Squeeze Lifetime Carbon Nanotubes were studied using this technique.

In 2016, Salih and his team of researchers investigated how nanomaterials affected the rheological and filtration properties of water-based drilling fluids.

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Fig.1 Carbon nano particles/powder

METHODOLOGY

This study is to use locally sourced additives in their nano scale and carbon nano particle (CNP) materials in formulating a water base mud of nano-base muds that will improve rheological performance at drilling conditions. From a theoretical as well as a practical perspective, investigating nano-base mud and the applications it may have is an intriguing subject. This mud system will enhance wellbore instability, depleted reservoir and stress caging issues.

The carbon nano particles were used to formulate a water base mud and the rheological properties analyzed comparing with API standard, Comparison of CNP mud formulation with the Conventional water base mud and also an economic comparison of the carbon nano particles with the conversional drilling additives

The extraction of carbon nano particles

The carbon nano particle was obtained from the fabricated equipment by injecting nitrogen into the vaporizer periodically without a catalyst. The catalyst was vaporized using a mixture of acetylene and argon gas. After that, the catalyst was heated in a reactor. Inside the reactor, a smoky substance was discovered. Condenser-cooled carbon nanoparticles are collected in the reactor's cyclones by this product after reacting with carbon nanoparticles.

RESULT AND DISCUSSION

Experimental measurements for water-based mud fluid loss agent were conducted with respect to API standard. Two mud samples were formulated with the same measurement of additives

Table 1 present the quantities of additives used during the water mud formulation process. API filter press assembly and filter paper were used for the fluid loss test.

Table 1. The Water Base Mud Formulation Kcl/Polymer Mud Comparing Soltex and CN

ADDITIVES	SAMPLE 1(SOLTEX)	SAMPLE 2 (CNP)
H2O (mls)	322	322
SODA ASH (g)	0.25	0.25
CAUSTIC SODA (g)	0.25	0.25
KCL (g)	25	25
PAC R (g)	1	1
PAC L (g)	2	2
SOLTEX/CNP (g)	1	1
BARITE (g)	77	77

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Table 2. Rheological Result Comparing Soltex and CNP

PROPERTIES	SAMPLE 1(SOLTEX)	SAMPLE 2 (CNP)
PLASTIC VISCOSITY (cp)	19	17
YEILD POINT (100ft ²)	16	31
FLUID LOSS (mls)	8.2	6.2
CHLORIDE CONTENT (mg/l)	40,000	41,000
SIZE OF FILTER CAKE (mm)	1.9	1.8

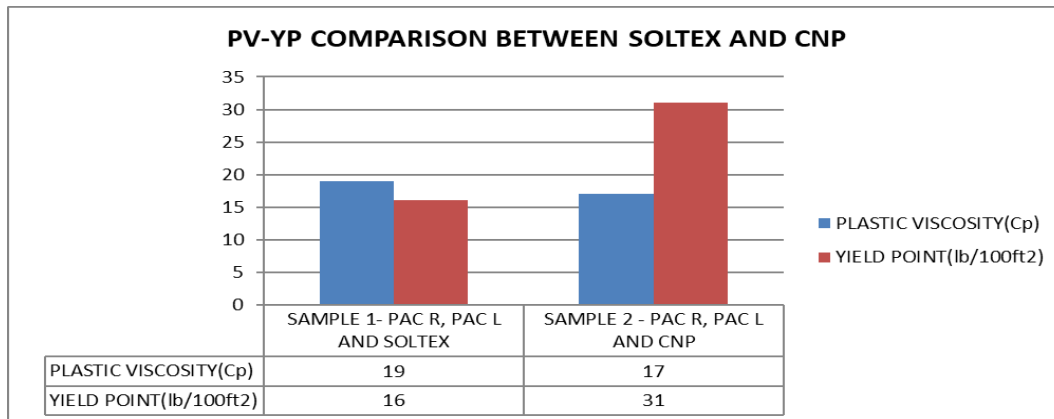


Figure 2. A Plot Comparing Soltex and CNP in Water Base Mud Formulation Kcl/Polymer

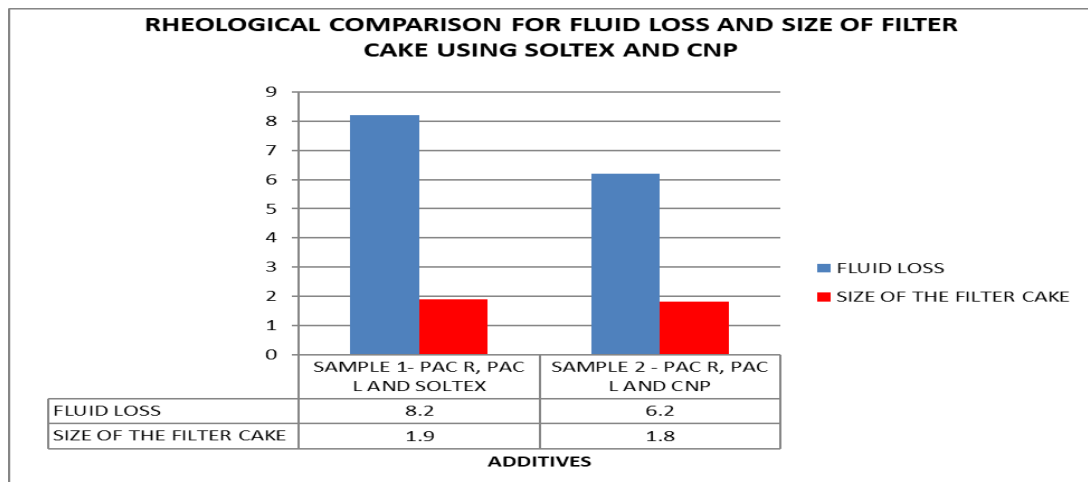


Figure 3. Comparing Fluid loss and filter cake for Soltex And CNP In Water Base Mud Formulation Kcl/Polymer

The result in figure 2 and 3 where the plot shows the comparison of the soltex and CNP in water base mud formulation where CNP is partially soluble in water base mud which does not contribute to the PV of our mud as compared to soltex which has a higher PV of 19 to CNP 17 showing soltex did not dissolve in the mud compared to CNP also CNP gave a better result for the fluid loss which can be used as a fluid loss properties in our mud. (Sample 1 and 2 where the CNP gave 6.2mls while soltex gave 8.2mls)

For sample 2 using CNP mud gave (0.18cm) and sample 1 (0.2) which shows using CNP gave a thin and firm filter cake as compared to soltex mud which is the conventional additives

Effect of Locally Formulated Mud on Shale Stability

The effect of shale (Smectite) which is one of the shale clay materials that swells more in terms of the shale types we have in the Niger Delta. The shale sample was obtained from one of the fields in Niger Delta (A field) and was analyzed using local formulated sample for eighteen hours to determine its swelling characteristics. It was observed that that the local formulated mud i.e., carbon nano particles and other local additives inhibits the swelling tendencies of shales as there was minimal effect on the shale sample. The shale was weighed before immersion in the formulated mud and was also weighed after eighteen hours to see the swelling effect and the result is shown in Table 3 below

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Table 3. Effect of the mud on shale reactivity

	SAMPLE1 PAC-R, PAC-L & SOLTEX	SAMPLE2 PAC-R, PAC- L& CNP	SAMPLE3 PAC-R& PAC L	SAMPLE4 PAC-R& CNP
WEIGHT BEFORE AGING	48.1	45.2	49.2	42
WEIGHT AFTER AGING	49.2	46.5	51.7	43.9

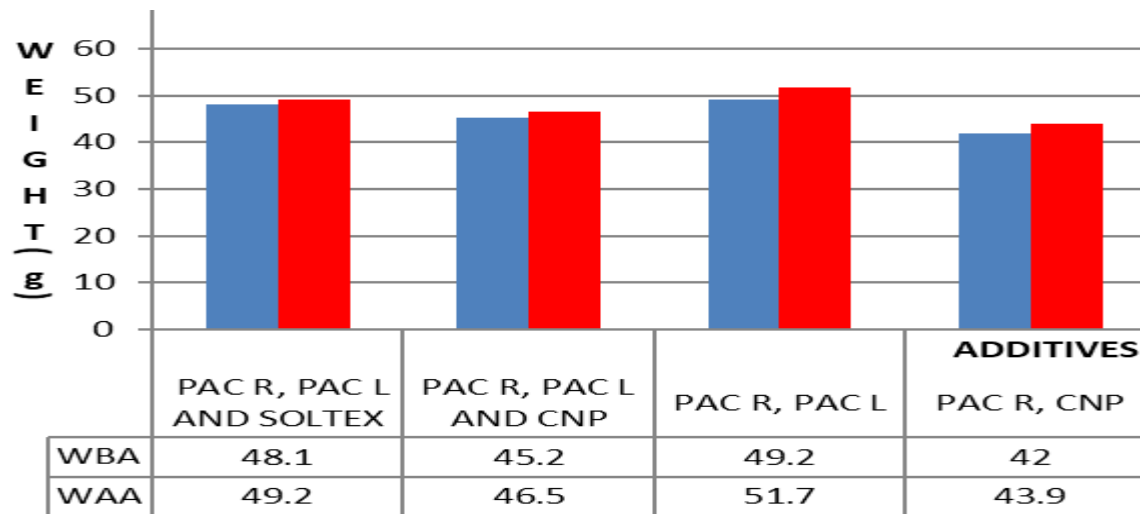


Figure 4. Effect of Shale Reactivity on Mud before and After Aging

Drilling Fluid Cost Analysis

When the section gets deeper, the cost of the fluid goes up because more fluid is required. Prices are determined by the cost of building and maintaining a specific mud weight. The total cost of constructing a mud system includes the price of all the components, the time it takes to mix them, and the estimated cost of the additives and chemicals used. An oil and gas company provided the information used in this study.

Table 4. Material Estimation per well of WBM Formulation for a 16" hole size 10ppg Kcl/polymer mud using Soltex

PRODUCT	UNIT SIZE	UNIT	COST/UNIT (USD)	TOTAL (USD)
CAUSTIC SODA	25kg	13	45.00	585
SODA ASH	25kg	13	25.00	325
KCL	1mt	46	1200	55200
PAC R	25kg	105	90.00	9450
PAC L	25kg	105	126.00	13230
SOLTEX	50lb	230	104.00	23920
BARITE	1mt	201	350.00	70350
TOTAL				173060

Table 5. Material Estimation per well for WBM formulation for a 16" hole size 10ppg Kcl/polymer mud using CNP

PRODUCT	UNIT SIZE	UNIT	COST/UNIT(USD)	TOTAL(USD)
CAUSTIC SODA	25kg	13	45.00	585
SODA ASH	25kg	13	25.00	325
KCL	1mt	46	1200	55200
PAC R	25kg	105	90.00	9450
PAC L	25kg	105	126.00	13230
CNP	50lb	230	25.00	5750
BARITE	1mt	201	350.00	70350
TOTAL				154890

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Table 6. Comparison per well of the mud cost analysis for WBM formulation

FORMULATION USING DIFFERENT ADDITIVES	TOTAL(USD)
SOLTEX	173060
CNP	154890

CONCLUSION

From the result of the experimental, we can say carbon nano particles can be used to substitute soltex which is the conventional additives for water-based mud as a fluid loss agent i.e. improve the fluids rheological and also optimizes viscosity, enhanced fluid loss control and stabilizes shale and they exhibit higher thermal conductivity

It also shows that the locally sourced CNP is a good shale inhibitor (particles inhibit the swelling tendencies of shales and helps reduce drilling problems). It can serve local substitution and save foreign exchange and improve local content in the oil and gas industry and it has export potentials in the Gulf of Guinea and other oil provinces

NOMENCLATURE

SBM	Synthetic base mud
OBM	Oil base mud
WBM	Water base mud
PV	Plastic viscosity
YP	Yield point
oF	Degree Fahrenheit
OC	Degree Celsius
MW	Mud weight
OWR	Oil water ratio
PPG	Pounds per gallon
CNP	Carbon nano particles
CNT	Carbon nano tube
MWCNT	Multiwalled carbon nano tube
WBA	Weight before Aging
WAA	Weight after Aging

REFERENCES

- 1) Abdul, RI; Tan, CS; Nor, AB; Wan, R; Wan, S (2014). "Improve Performance of Water-based Drilling Fluids
- 2) Abouzar M.P, Bandar D.A (2008). "Using Nanoparticles to Decrease Differential Pipe Sticking and its feasibility in Iranian Oil Fields". Oil and Gas Business.
- 3) Agarwal, S.; Tran, P.; Soong, Y.; Martello, D.; Gupta, R.K. (2011). Flow Behavior of nanoparticle stabilized drilling fluids and effect of high temperature aging. In Proceedings of the AADE National Technical Conference and Exhibition, Houston, TX, USA, 12–14 April 2011.
- 4) Amanullah, Al-Arfaj, M., & Alabdullatif, Z.A. (2011). Preliminary Test Results of Nano-based Drilling Fluids for Oil and Gas Field Application. *Distributed Computing*.
- 5) Ghorbani, N; Wilson, MC; Kapur, N; Fleming, NA; Neville, (2014). studied Carbon Nanotubes on approach used for Enhanced Squeeze lifetime CNTs. Journal of Petroleum Exploration and Production Technology. <https://doi.org/10.1007/s13202-019-0689-7>
- 6) Iijima S. (1991). Helical microtubules of graphitic carbon. *Nature*. 354:56–58. M. O. Onyekonwu, N. A. Ogolo, Investigating the Use of Nanoparticles in Enhancing Oil Recovery, Nigeria Annual International Conference and Exhibition, 2010.
- 7) Ismail, AR; Seong, TC; Buang, NA; Sulaiman, WRW (2014). Improve Performance of Water-Based Drilling Fluids Using Nanoparticles. Palembang, The 5th Sriwijaya International Seminar on Energy and Environmental Science & Technology

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- 8) Iyuke, SE; Mamvura1, TA; Liu, K; Sibanda, V; Meiyappan M; Varadan, VK (2009). 'Process synthesis and optimization for the production of carbon nanostructures' IOP PUBLISHING Nanotechnology 20 (2009) 375602 (10pp) doi:10.1088/0957-4484/20/37/375602.
- 9) Nabhani, N., & Emami, M. (2012). THE POTENTIAL IMPACT OF NANOMATERIALS IN OIL DRILLING INDUSTRY. NANOCON 4th International Conference Proceedings. Brno, Czech Republic, EU doi: 10.1038/354056a0.
- 10) Nasser, J; AnnaJ, TM; Majid, Al; Ruqeshi, GD; Shahjahan, M (2013). Experimental Investigation of Drilling Fluid Performance as Nanoparticles. World Journal of Nano Science and Engineering, 2013, 3, 57-61 <http://dx.doi.org/10.4236/wjnse.2013.33008> Published Online September 2013 (<http://www.scirp.org/journal/wjnse>).
- 11) Ogolo, NA; Olafuyi, OA; Onyekonwu, MO (2012). Enhanced Oil Recovery using Nanoparticles, SPE 160847 Saudi Arabia Technical Symposium and Exhibition, 8th – 11th April, Alkhobar, Saudi Arabia.
- 12) Ogolo, NA; Onyekonwu, MO; Akaranta O (2013). Trapping Mechanism of Nanofluids on Migrating Fines in Sand" SPE 167502. 37th Nigeria International Conference and Exhibition, 30th July – 1st August in Lagos.
- 13) Rafique, M. M. A., & Iqbal, J. (2011). Production of carbon nanotubes by different routes—A review. Journal of Encapsulation and Adsorption Sciences, 1, 29–34. <http://dx.doi.org/10.4236/jeas.2011.12004>
- 14) Salih, AH; Elshehabi, T.A; Bilgesu, HI (2016). Impact of Nanomaterials on the Rheological and Filtration Properties of Water-Based Drilling Fluids. One petro Paper presented at the SPE Eastern Regional Meeting, Canton, Ohio, USA, September 2016. Paper Number: SPE-184067-MS <https://doi.org/10.2118/184067-MS> Published: September 13 2016
- 15) Sedaghatzadeh, M., Khodadadi, A., Tahmasebi birgani, M. (2012). An Improvement in Thermal and Rheological Properties of Water-based Drilling Fluids Using Multiwall Carbon Nanotube (MWCNT). Iranian Journal of Oil and Gas Science and Technology, 1(1), 55-65. doi: 10.22050/ijogst.2012.2775
- 16) Smalley R. E., (1993). From dopyballs to nanowires, *Mater. Sci. Eng. B* 19, 1-2 Pages 1-7, ISSN 0921-5107, [https://doi.org/10.1016/0921-5107\(93\)90156-H](https://doi.org/10.1016/0921-5107(93)90156-H).
- 17) Vikas Mahto and Rajat Jain, (2013). Effect of Fly Ash on the Rheological and Filtration Properties of Water Based Drilling Fluids Ijret: International Journal of Research In Engineering And Technology Eissn: 2319-1163 | Pissn: 2321-7308



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