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Enhancement of Drilling Fluid Properties Using Nanoparticles

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Abstract

Nanotechnology has shown a lot of promise in the oil and gas sectors, including nanoparticle-based drilling fluids. This paper aims to explore and assess the influence of various nanoparticles on the performance of drilling fluids to make the drilling operation smooth, cost effective and efficient. In order to achieve this aim, we exam the effect of Multi Wall Carbon Nanotube and Silicon Oxide Nanoparticles as Nanomaterial to prepare drilling fluids samples.

Anew method for mixing of drilling fluids samples using Ultra sonic path principle will be explained. Our result was drilling fluids with nano materials have high degree of stability.

The results of using Multiwall Carbon Nanotube and Silicon Oxide show that MWCNT have an effect on rheological properties more than SiO2 and good thermal conductivity. Also, both nano particles have potential effect on filter loss and stability of mud. The change in density was insignificant which is beneficial for many drilling operations.

Keywords: Drilling Fluids properties, Multi Carbon Nanotube, Silicon Oxide Nanoparticles.

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1- Introduction

Different fluids such as drilling, drill-in, and completion used in drilling and production operations. Which consider complex systems that contains a multi phases such as fluid phase, a solid phase and a chemical phase. The solids, chemicals and polymers which are used in designing the fluids, will take a major role in functional behavior of the fluids. Although there are diverse factors that control the select of fluid base and the mud additives, for a trouble free drilling and economical drilling and production operations, the selection of the additives should take into concern both environmental and technical challenges. The capability of nano technology to be custom made with certain properties will take a major role to defeat the environmental and technical challenges which may occur during drilling and production.

It is more likely to encounter new technical challenges in the drilling and production process due to continuous change in the circumstances of drilling such as operational depth, with increasing depth comes subsurface geo-hazards, increasing of horizontal departure to provide maximum production, complication of the drilling operation, shape of wellbore profiles or number of laterals from a motherbore to maximize reservoir contact.

Also another material related challenge is because the considerable change in chemical, physical and thermal conditions of deeper horizons with more and rougher environmental rules legislates by different governing bodies. So the industry is in continuous searching for chemicals that are physically small, mechanically strong, with stability in the chemical and thermal composition, can be biologically degrade to some level.

Comparing to other materials, the nanos are the most likable materials of choice for smart fluid design for oil and gas application since it has wide range of variation and high enhanced mechanical, thermal, physio-chemical, electrical, hydrodynamic properties and the possibility to interact of nano materials compared to other materials.

Thus the nanos are most likely to be the best choice to be used in smart fluid design oil and gas field application. This development in the materials will provide a new class of fluids used in drilling, production and stimulation related applications defined as smart fluids.

In oil and gas industry, Nano fluids may be defined as any fluid that is used in drilling, drill-in, completion, stimulation processes, etc. that have at least one additive with Nanoparticle size in the rangei of 1-100 nanometers.

Nano expression is given toi particles that havei a dimension that is thousand millionths of a meter.

The fluids can be classified as simple and advanced nano-fluids based on the amount of nano-sized additives in the fluid. Simple nano-fluids are the fluids with onei nano-sized additive while advanced nanofluids are the fluids with more than ione nano-sized additive. From functional points of view, nano materials could be classified as single functional and multifunctional.

Multifunctional nano-additives will perform a multi jobs in the fluid systems which will lead into completing the functional tasks of the fluid with high reduction in total solids and/or chemicals content used in the mud which will finally lead to reduction of total fluid cost.

One of characteristic features of using nano-based smart fluids is the reduction of overall fluid cost although the individual additives are consider high cost but with remarkable higher functional ability.

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The laws that control the nano scale material behavior is totally different from the ones that control the micro and macro scale behavior, this is because of beyond colloidal sizes of nanos with their close proximity to the atomic scale compared to macros and micros. This difference in behavior can be highly noticed in the behavior of carbon nano tubes from those of graphite although both these materials were derived from the graphite mother source [1].

2- Drilling Fluid Properties

2.1. Density

Is one of importance properties in drilling fluids. It is used for controlling the pressure and all calculation of pressure control are done based on the density of the mud column in the hole. Baroid Mud Balance as shown in Fig. 1 is used to determine drilling fluid density. The instrument consists of a constant volume cup with a lever arm and rider calibrated to read directly the density of the drilling fluids [2].

Fig. 1. Mud Balance

2.2. Rehoelogical Properties

Rheology refers to the deformation and flow behavior of all forms of matter. Certain rheological measurements made on fluids, such as apparent viscosity (AV), plastic viscosity (PV), gel strength, and yield point (YP) etc. help determine how this fluid will flow under a variety of different conditions. This information is necessary in the design of mud circulating systems required to achieve certain desired goals in drilling operations as its resistance to flow. The required viscosity for a particular drilling fluid operation is influenced by many factors, including mud weight, hole size, pumping rate, rate of drilling, pressure system and requirements, and hold problems. The indicated viscosity as obtained by a rotational viscometer instrument shown in Fig. 2 is valid only for that irate of shear and will differ to some degree when measured at a different rate of shear [3].

Fig. 2. Rotational Viscometer

2.3. Mud Filter Loss

Is the calculation of filtrate passing from the drilling fluid into a porous permeable formation. Low fluid losses are a characteristic of excellent drilling fluids and the key to borehole stability. The aim of a good drilling fluid is to create a thin mud cake on the wall of the borehole. This prevents the extra loss of fluids into the formation. The drill pipe may stick to the borehole of the well due to the formation of filter cake or a layer of wet mud solids on the wall of the hole in the formation. The filtrate loss at variety pressures is measured using the filter press tool as shown in Fig. (3) [4].

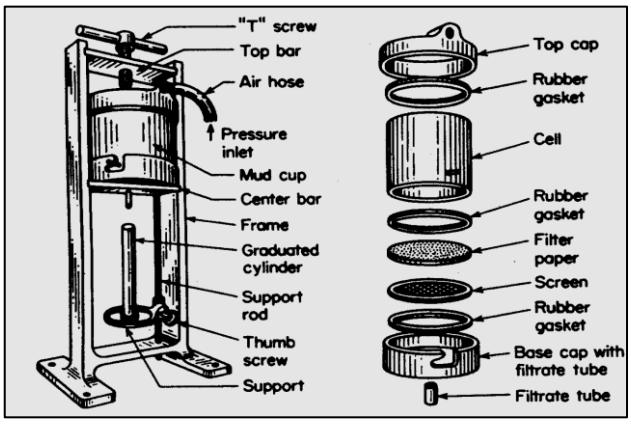

Fig. 3. Filter Press

2.4. Thermal Conductivity

Nano fluids are exhibited superior heat transfer properties compared with conventional drilling fluids heat transfer. Also, it is known that thermal conductivity of Nano fluid is dependent on the volume fraction dimensions and properties of nanoparticles used. By using nanoparticles in heat transfer, the performance of drilling fluid can be significantly improved due to increase surface area to volume ratio [5].

Stability of Mud is generally generated by its homogeneity after a long aging period. In water base mud, the phase separation is an indicator of mud stability. Surface force are more important than gravity force in

controlling colloidal behavior system, this is due to high surface area to volume ratio in Nano fluids. Zeta meter concept is used to measure the stability on Nono fluids by measuring the effect of electrostatic charge between particles. The zeta meter instrument is shown in Fig. 4 [6].

Fig. 4. Zeta Meter System

3- Experimental Work and Samples Preparation

The type of drilling fluid that used in this research is Ferro Chrome Lignosulphonate (FCL) which is used in south Iraq oil fields. This mud can be preparation in easy way. Prehydrated of bentonite fluid should be made first by adding 25 gm sodium bentonite with 400 ml fresh water and mix it at least for 20 min using Mixer Hamilton Beach and let it for 24 hrs for hydration. After that adding 0.15 gm caustic soda to improve the performance of lignosulphonate and rise PH values. 0.15 soda ash is used to treat out calcium ion and to benefaction calcium bentonite. 30 gm of barite is adding to increase mud density.

Lignosulfonate is used to control rheology and provide filtration control through deflocculating the bentonite in weight of 0.5 gm. After that Nano particles of MWCNT and SiO2 is added to fluid at laboratory condition in concentration of 0.25, 0.5, 0.75, and 1 gm and mix them for 30 minutes using Mixer Hamilton Beach. After that the fluid is exposed to ultrasonic bath for 30 minutes to ensure good dispersion for nono particles inside fluid as shown in Fig. 5. The nanoparticles are added to fluid in small amount, with low concentration (less than 1%).

The nanoparticles have the following properties:

For multi wall carbon nanotube:

a. Purity: +95%
b. Outside diameter: 5-15 nm
c. Length: 10-20 nm
d. Form: powders
e. Color: black

For silicon oxide nano particles:

a. Purity: 99%
b. Diameter: 10-30 nm
c. Form: powder
d. Color: white

Fig. 5. Ultra sonic path

4- Results of the Experimental Work

4.1. Density Results

Due to importance of mud density, the effects of MWCNT and SiO2 nanoparticles were investigated. Increase in the mud density by adding nanoparticles is insignificant. By considering Fig. 6, density of all nanofluids changes with concentration in the same way. The reason that MWCNT increase mud density more than SiO2 is due to the tubular structure of MWCNT like hollow tubes, and their clusters inside mud have the ability of trapping the larger volume of fluid comparison with the cluster of silica nanospheres. Thus, MWCNT clusters could reduce volume of the nano fluids, and finally increase its density more than others.

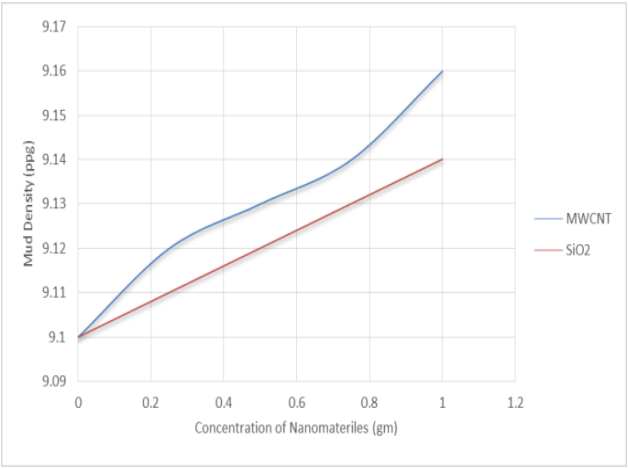

Fig. 6. Effect of nanomaterials concentration on density of drilling mud

4.2. Rheological Properties

The presence of nanomaterials will increase apparent viscosity of the fluid as a result of the interactions between the particles and liquid molecules as shown in Fig. 7.

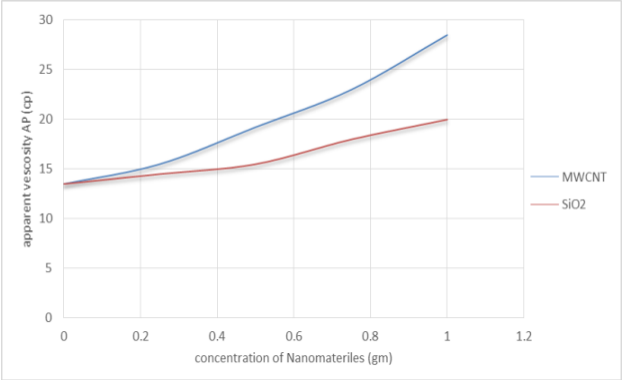

Fig. 7. Apparent viscosity changes with nanomaterials concentration

It is obvious from the above figure that MWCNT high viscous than SiO_2. In some cases, MWCNT are highly entangled, and form a skein inside the fluid when they are dispersed, and it would result in highly viscous behavior in a nanofluid, while the spherical structure of nano silica causes easier movement inside the fluid layers.

For the plastic viscosity, which is indicates the resistance to the flow produced be mechanical fraction, the results show no changes in values of PV. Fig. 8 shows the change between plastic viscosity and concentration of nano fluid.

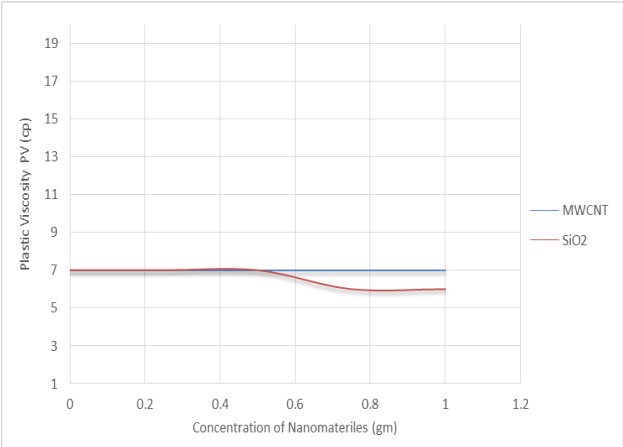

Fig. 8. Plastic viscosity changes with nanomaterials concentration

For yield point results, generally the yield point of nano fluids is higher than conventional mud. The increase in yield point will provide better suspension of drilling cuttings and efficient cleaning of the wellbore while drilling. The increment of yield point is due to high surface areas per volume and it will increase the interaction of the nanoparticles with the matrix and surrounding base fluid. Fig. 9 shows yield point changes with nanoparticles concentration.

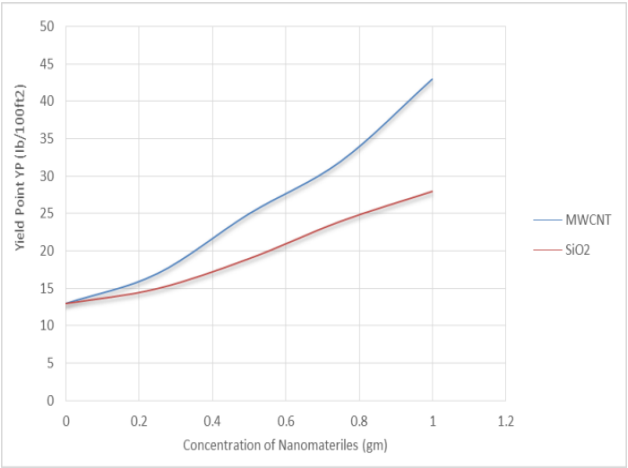

Fig. 9. Yield point changes with nanoparticles concentration

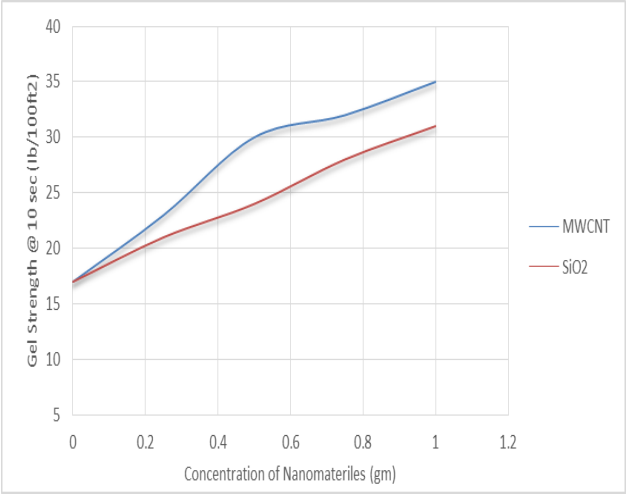

Fig. 10. The effect of nanoparticles on gel strength at different concentrations at 10sec

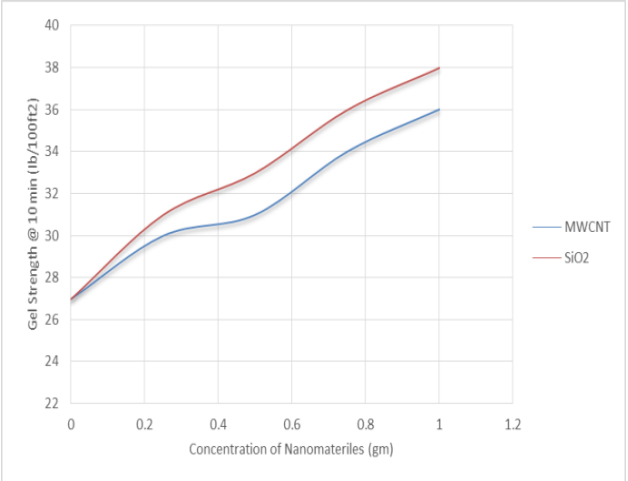

Fig. 11. The effect of nanoparticles on gel strength at different concentrations at 10 min

For gel strength, nanofluids show an increasing in gel strength with increasing concentration of nanoparticles.

This occurs because of electrostatic force between nanoparticles which cases link together with base fluids to form a rigid structure. Fig. 10 and Fig. 11 show the effect of nanoparticles on gel strength at different concentrations at 10sec and 10 min respectively.

4.3. Mud Filter Loss Results

The effect of nano particles on mud measured in terms of fluid loss has been shown in Fig. 12. It can be say that the normal drilling fluid will lose its filtrate more than nanomud. This means that the amount of filtrate is decreases slightly with time by increasing the concentration on nanoparticles of MWCNT and SiO2, which is result in decreasing of pipe sticking problem.

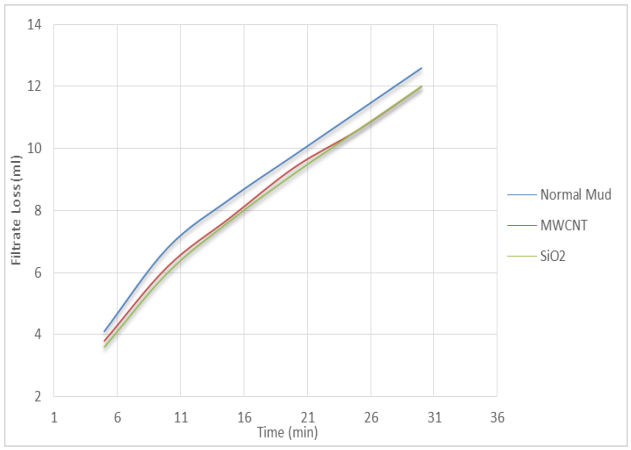

Fig. 12. Fluid Loss for nanomud and normal mud with increase in time

From the laboratory observation, the filter cake of nanomud can form an effective lubricating film to reduce pipe sticking inside the wall; this can be shown in Fig. 13. It can provide enough reduction of fraction between pipe and borehole also provide easy sliding of the drill string which is good solution for torque and drags problems of horizontal drilling wells.

Fig. 13. Very fine and thin film of MWCNT mud cake

4.4. Thermal Conductivity Results

Adding polymer materials to drilling fluids would lose their effectiveness at high temperature conditions, which result in operation problems such as barite sag. Nanoparticles can be used to improve the ability of thermal conductivity. Fig. 14, Fig. 15 and Fig. 16 show changes in apparent viscosity, plastic viscosity and yield point of the nano fluids with concentration at different temperatures.

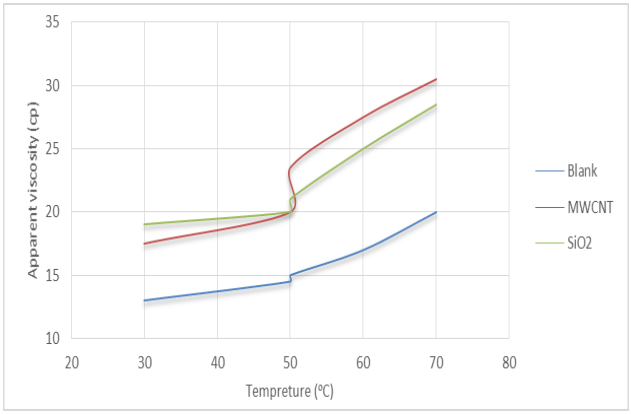

Fig. 14. Changes in apparent viscosity of drilling fluids with the temperature at concentration of 1 gm nanoparticles

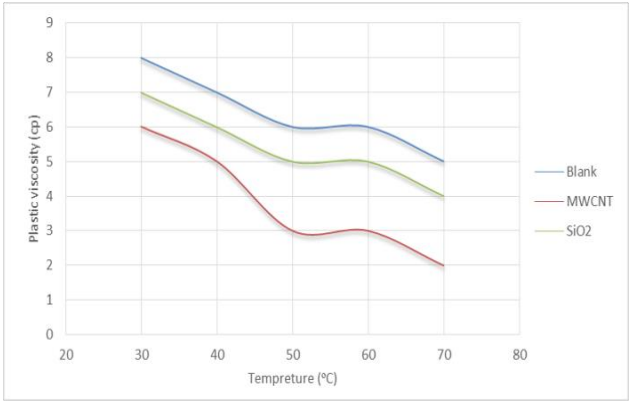

Fig. 15. Changes in plastic viscosity of drilling fluids with the temperature at concentration of 1 gm nanoparticles

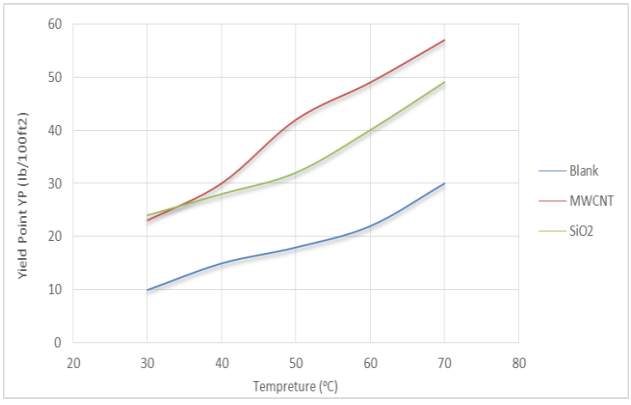

Fig. 16. Changes in yield point of drilling fluids with the temperature at concentration of 1 gm nanoparticles

5- Conclusion

1- Due to the amount of nano-particles required for any application is too low (Typically<1%) which reduces the total cost to a great extent.
2- Increasing in density was too low, which means low horsepower to circulate the mud through the well circulation system.
3- Due to the strong particle-particle interaction, several nanomaterials can act as viscosifiers and filter loss agent because rheology and fluid loss control are two areas basic to drilling fluids that appear to be suited for the application of nanotechnology.
4- From zeta potential calculation, we conclude that drilling fluids with nano particles have high degree of stability.
5- The thickness of a filter cake is dependent on the fluid loss or leak off into the formation. When using nano fluids, virtually very thin filter cake forms in the wellbore because of permeability reduction at short time and quickly make up of filter cake.
6- Nano particles can work as toolbox to activate other properties of drilling fluids, such as viscosity, gel strength, filter loss control, and friction reduction.

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تأثير مواد الإضافة النانوية على خواص سائل الحفر

أظهرت تقنية النانو مستقبل واعد في قطاع صناعة النفط و الغاز و التي تتمثل بموائع الحفر ذات الاساس النانوي. هذة الدراسة تهدف لشرح و توضيح تأثير مواد نانوية مختلفة على ادائية سوائل الحفر لجعل عمليات الحفر اكثر سهولة و مرنة و مجدية من الناحية الأقتصادية. و لكي يتم انجاز الدراسة, تم اختبار تاثير الكاربون متعدد الجدران النانوية و اوكسيد السيليكون النانوي لتحضر نماذج سوائل الحفر و فحص خواصها.
تم استخدام طريقة لغرض خلط نماذج الحفر باستخدام الموجات فوق الصوتية قد قدمت في هذة الدراسة و ايضا طريقة جديدة لغرض اختبار استقرارية الطين قد تم شرحها في هذة الدراسة, النتائج اعطت استقرارية عالية لطين الحفر الذي يحتوي على مواد نانوية.
تم استخدام طين Ferro chrome lignosulfonate لدراسة تاثير المواد النانوية. النتائج اظهرت بان الطين يسلك الموديل power law and Bingham models. تاثير المواد النانوية على الكثافة كان قليل نوعا ما حيث ارتفعت بمقدار 4% للSiO_2 و 6% لل MWCNT. مقدار التغير باللزوجة الظاهرية كان بمقدار 15 cp لل MWCNT و بمقدار 6.5 cp لل SiO_2. التغير باللزوجة البلاسيتيكية كان قليل جدا او غير محسوس مع نقصان قليل بالنسبة للSiO_2 بسبب الشكل الكروي الذي يأدي الى تقليل الاحتكاك بين الجزيئات. الزيادة في نقطة الخضوع كانت بمقدار 30 Ib/100 ft^2 بالنسبة لل MWCNT و بقدار 15 Ib/100 ft^2 للSiO_2 و السبب يعود الى نسبة العالية للشد السطحي الى الحجم للمواد النانوية. مقدار التصلب لطين الحفر كان عالي بسبب قوى التماسك الكبيرة للمواد النانوية. التجارب اظهرت مقدار ترشيح قليل للاطيان التي تحتوي على مواد نانوية بسبب حجمها الصغير مما يؤدي الى غلق مسامات ورقة الترشيح بسرعة كبيرة. ان كعكة الطين المتكونة على ورقة الترشيح كانت رقيقة جدا و ذات خواص زيتية مما يعطي انطباع جيد لحل مشكلة استعصاء الانابيب. الاطيان التي تحتوي على مواد نانوية اظهرت درجة عالية من الاستقرارية و السبب يعود الى كمية الشد السطحي العالية الى الحجم.