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Improving the Drilling Fluid Performance by Alumina Oxide Nanoparticles

Samir M. Khaled[1] and, Zeyad H. H[2]

Al-Azhar University, Faculty of Engineering, Mining & Petroleum Eng. Department, Cairo, Egypt[1]

B.Sc. in Petroleum Engineering, Cairo, Egypt[2]

Abstract: Nanotechnology has made revolutionary changes in various fields of engineering and is expected to have a great potential in improving oil and gas industry in the next few years. Nanotechnology has introduced the nanoparticles that were found very striking for petroleum engineers to be used in different petroleum applications. The extremely tiny size and large surface area to volume of nanoparticles gave them the capability of upgrading several operations including exploration, drilling, completion, production and processing.
In this paper, a study of how nanoparticles can be used to improve the drilling operation by upgrading drilling fluid properties is conducted in the manner of eliminating or decreasing the probability of drilling problems. An experimental study is steered and discussed in order to evaluate the effect of adding Alumina oxide nanoparticles to a water base drilling mud. Nanoparticles were tested by the X-ray diffraction (XRD) which confirmed their identity and Transmission Electron Microscopy (TEM) which confirmed that the average particle size is in the range of 60 nm to 90 nm, these tests were carried out at the Egyptian Petroleum Research Institute (EPRI).

A conventional drilling fluid was prepared at the British University in Egypt fluids lab and was tested with the intention of appraising its characteristics, namely Low shear yield point (LSYP), yield point, gel strength, fluid filtrate volume and mud cake properties. Same tests were conducted on a Nano-enhanced fluid for the sake of constructing a comparative analysis between the two fluids in terms of the mentioned parameters. Three samples of drilling fluid with different nanoparticles w/w concentrations were prepared in order to determine the optimum nanoparticle concentrations that will yield the best results. A reduction of the filtrate volume to about 45% accompanied with a reduction of the mud cake thickness to about 42 % were observed at a concentration of 1.5 wt% of Alumina oxide nanoparticles in the water base fluid, this indicates the great capability and potentiality of Nanofluids to minimize the probability of differential pipe sticking and formation damage. Enhancements of the rheological properties were observed, and valuable amounts of drilling fluids were saved.

Keywords: Nanoparticles, Drilling fluids, Water Bas Mud, Alumina oxide.

INTRODUCTION

Drilling problems anticipated are loss of circulation, differential pressure pipe sticking and formation damage. Nano-based drilling fluids will aid in reducing severity of these problems or eliminating them by various means. Critical characteristics of drilling fluids should be maintained in order to eliminate the reasons of drilling problems may that be encountered during drilling troublesome formations. Depending on formation and well characteristics, special additives are added to the drilling fluid to obtain the desired qualities. Nanoparticles suspension in the drilling fluid was proven to improve its aspects in a way that upgraded its qualities to overcome harsh conditions of drilling. A laboratory study on Silicon Nanoparticles in drilling mud compositions was conducted to investigate the effect of the same on mud cake thickness. The results indicated that the additional 3% by volume of silicon nanoparticles has results in decreasing the mud cake thickness by 34 % (Saket et.al, 2011). An experimental study on Nanoparticles Loss of circulation materials has been conducted. All Nanoparticles were prepared with the oil base drilling fluids. Under low pressure -temperature API standard test, more than 70% reduction in the fluid loss was achieved in the presence of Nanoparticles compared to only 9% reduction in the presence of typical loss of circulation materials. (Zakaria et al, 2012). A combination of calcium carbonate and graphite Nanoparticles was very effective at improving well bore stability by increasing the hoop stress in the near well bore (Aston et al, 2004). Stress Caging techniques using graphite, specifically sized calcium carbonate can be applied to improve will bore stability and reduce losses. (Vickers et al, 2007).

A Nano-size deformable synthetic polymer along with sized calcium carbonate and graphite was identified to effectively plug the pore throats and minimize the fluid invasion, which was confirmed by particle plugging tests. (Waleed et al, 2015). Water based mud formulations inclusive of Nanosilicas offer the possibility for improved shale inhibitors. These additives may be effective in maintaining well stability and in preventing equipment problems, (Peter et al, 2016). Nano-based drilling fluid will introduce thin smooth filter cake with low permeability which will decrease the likelihood of differential pressure pipe sticking as well as reducing the fluid invasion into the formation. In addition, nanoparticles will propagate towards the near wellbore vicinity blocking its pores, described as forming an internal mud

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cake, in a manner to further prevent fluid invasion into the formation thus decreasing formation damage. Chenevert and Sharma (2009) investigated permeability reduction of shale formations using Nanoparticles in the WBM drilling fluids. By identifying the pore throat radii of shale sample, the investigators were able to select fine particles that would fit into pore throat during the drilling process and create a nonpermeable shale surface.

EXPERIMENTAL PLAN

Experimental plan of this research aimed to study the effect of adding nano-aluminum oxide particles on the characteristics of the drilling fluids. Four samples of water base mud were prepared and different aluminum nanoparticles concentrations were added to three of them with values of 0.5%, 1% and 1.5% w/w. Comparing the Nano-based fluid with the conventional water base mud in terms of fluid filtration, mud cake thickness, Low shear yield point (LSYP), yield point and gel strength, in order to check the enhancement in the rheological characteristics resulted from the added Nano-particles. This enhancement will serve to avoid or mitigate some of the drilling problems that could be induced while drilling with conventional drilling fluid. These problems include pipe sticking, loss of circulation, formation damage, and poor hole cleaning. First, alumina-oxide nano powder will be tested by Transmission Electron Microscope (TEM) and X-ray Diffraction (XRD) in order to verify their size and identity. XRD lab report has confirmed the identity of the tested samples as Aluminum Oxide (Al_2O_3).

TEM high resolutions images presented on Figure 1, the structure of the Alumina particles as elongated rods, with a size falling in the Nano-scale of approximate average range of 60 to 90 nm. Aluminum Oxide was chosen for this investigation due to its low cost as a raw material. Also, it was proven that the Alumina nanoparticles dispersion will increase heat transfer and thermal conductivity of the fluid which will aid in increasing drill pipe and bit life and reducing the risks of pipe failure. A conventional water-base drilling fluid will be tested by the API filter press and OFITE Rheometer, results will be recorded. Nano-particles will be added to multiple samples with different concentrations for the same of concentration. Calculations of filtrate volume, Low shear yield point, yield point and gel strength will be conducted for each sample to check the enhancement achieved by added particles in addition to estimating the critical concentration of Nano-particles which achieves the best results with economic beneficial.

RESULTS AND DISCUSSION

Rheology of Nano-Water Base mud. Rheology can be defined as the study of the deformation and flow of matter, and is considered as the key of bottom hole cleaning in well drilling. The different values of Rheological parameters of Nano-particles mud were measured and tabulated in Table (1) and presented on Figures 2 through 6. The effect of Nano-Particles on rheological properties such as gel strength, low shear yield point, and yield are shown on Figures from 2 to 4, respectively. From these Figures, it is observed that increasing Nanoparticles of aluminum oxide concentration in the WBM improves rheological properties. In the other wards there is a direct relation between the aluminum oxide concentration and each of the LSYP, gel strength and yield point. This will results in reducing velocity of cuttings settling and consequently reduce differential pip sticking.

Filtrate volume of Nano-Water Base mud. The effect of Nanoparticles of aluminum oxide (NAO) on filtrate volume of mud is shown in Figure 5. This Figure indicate that increasing the NAO concentration in WBM to .5%, 1% and 1.5% has led to reducing the mud filtrate volume to 21 % , 30% and 45% respectively. This is because nanoparticles have plugged the pores of the formation at the near wellbore vicinity in a way that is illustrated as forming internal mud cake. Furthermore, it will yield a low permeable mud cake on the walls of the borehole. A dramatic reduction of fluid loss to the formation is expected as a result of the pore plugging and low permeability mud cake, consequently decreasing formation damage as a result of the less filtration volume.

Mud cake thickness. To prevent differential pipe sticking in the drilling operation, the mud cake thickness should be considered carefully. Figures 6 show the effect of NAO concentration in WBM on the mud cake thickness. This Figure indicate that increasing the NAO concentration in WBM to .5%, 1% and 1.5% has led to reducing the mud cake thickness to 16 %, 32% and 42% respectively. Nanoparticles are believed to fill the gap in the clay plates and this prevents further flow through the pores, and subsequently lower clay deposit and results in a thinner filter cake.

CONCLUSION

The following are the important conclusion from the present work.

1. Enhancement of the rheological properties of mud expressed in increasing the LSYP up to 4.2 (lbf/100ft^2) , Gel strength up to 5.6 (lbf/100ft^2) and yield point to 7.5 (lbf/100ft^2) at 1.5% wt NAO concentration. Thus, enhancing the mud ability to transport and suspend cuttings in the favor of improving bottom hole cleaning.

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2. Increasing the NAO concentration in WBM to .5%, 1% and 1.5% has led to reducing the mud filtrate volume to 21 %, 30% and 45% respectively. This will aid in reducing the filtration volume to the formation, hence reducing the drilling costs by saving a valuable amount of mud in addition to reducing the drilling induced formation damage.

3. Mud cake thickness has been reduced to 16%, 32%, and 42% due to increasing the NAO concentration to 0.5%, 1% and 1.5% respectively. Probability of the differential pressure pipe sticking is reduced when adding Nanoparticles to the drilling fluid as the mud cake thickness is reduced.

Table 1 Results of laboratory tests for WBM with additions Nanoparticle Aluminum Oxide (NAO)

Parameter	**WBM**	**WBM +.5 % NAO**	**WBM +1% NAO**	**WBM + 1.5 % NAO**
600 rpm	24	30	33	37
300 rpm	14	18	20	22
200 rpm	12	14	15	16
100 rpm	9	11	13	14
6 rpm	5	6	6	7
3 rpm	3	4	5	6
Gel at 3 rpm	3	4.5	5	5.5
PV (cp)	10	12	13	14.5
YP, ($lb/100\ ft^2$	4	6	7	7.5
Filtrate volume, mL	35	27.5	24.6	20
Filter cake thickness, mm	1.9	1.6	1.3	1.1

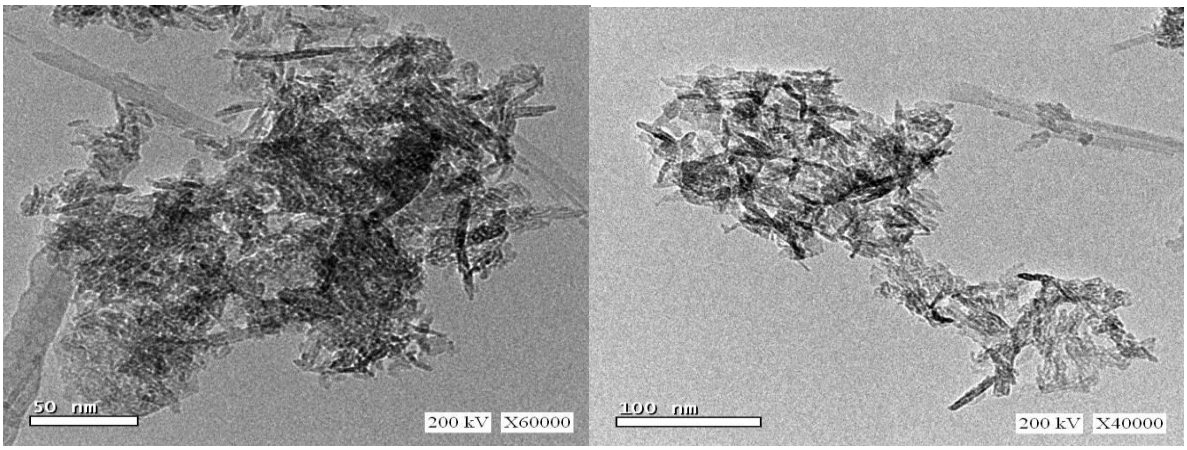

Fig. 1 TEM Photographs

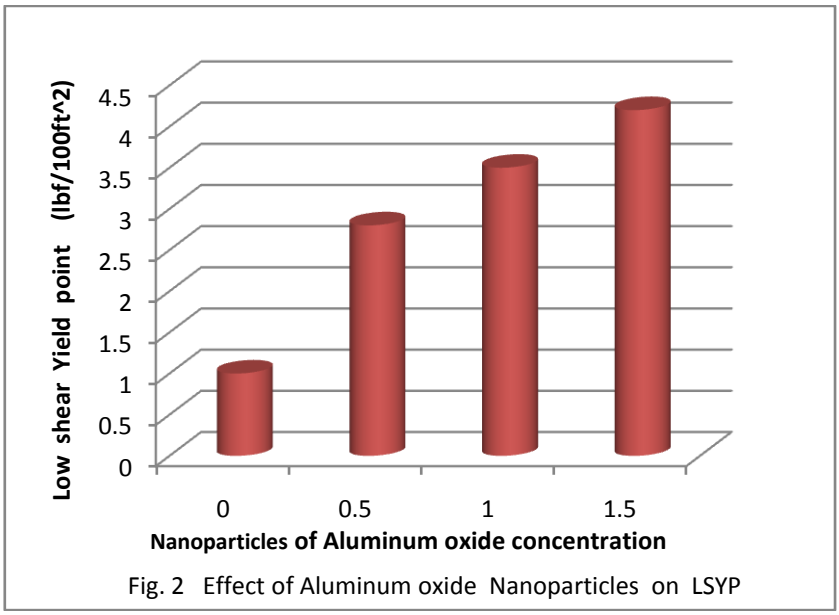

Fig. 2 Effect of Aluminum oxide Nanoparticles on LSYP

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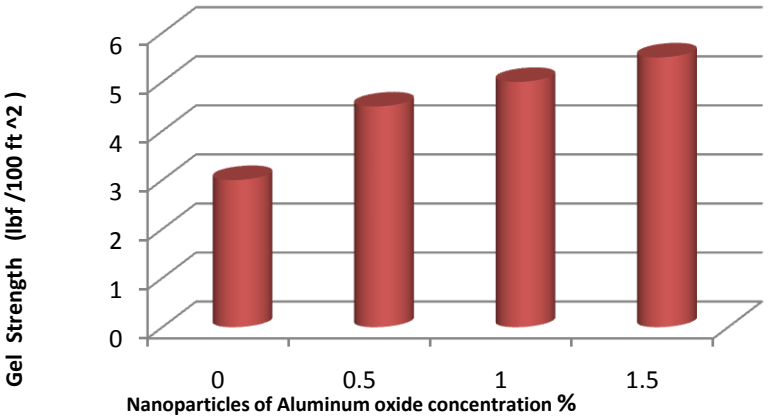

Fig. 3 Effect of Aluminum oxide Nanoparticles on Gel Strength

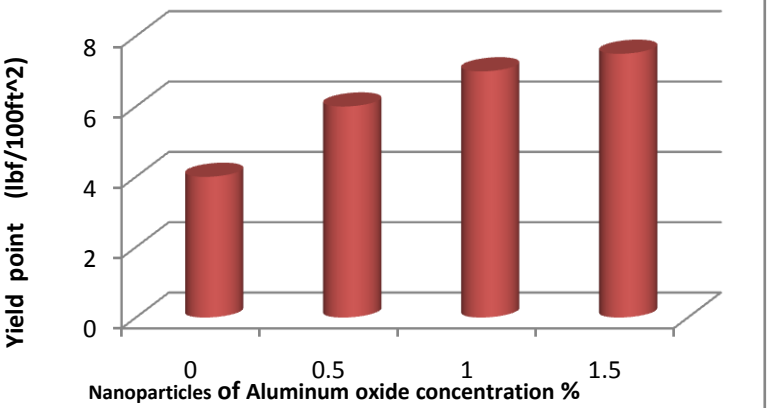

Fig. 4 Effect of Aluminum oxide Nanoparticles on Yield point

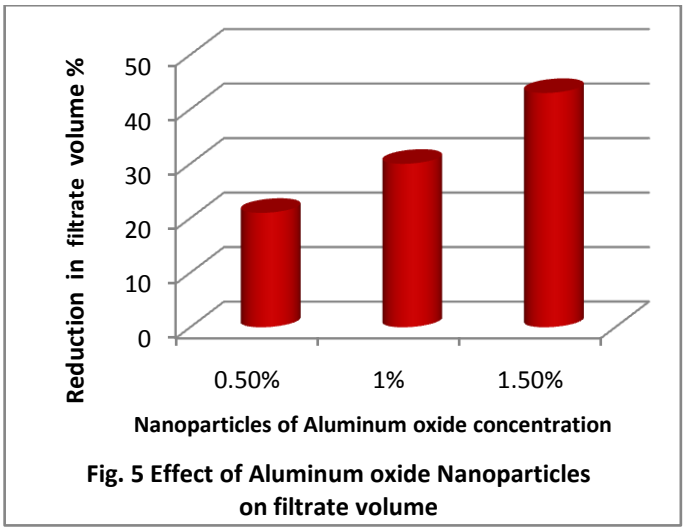

Fig. 5 Effect of Aluminum oxide Nanoparticles on filtrate volume

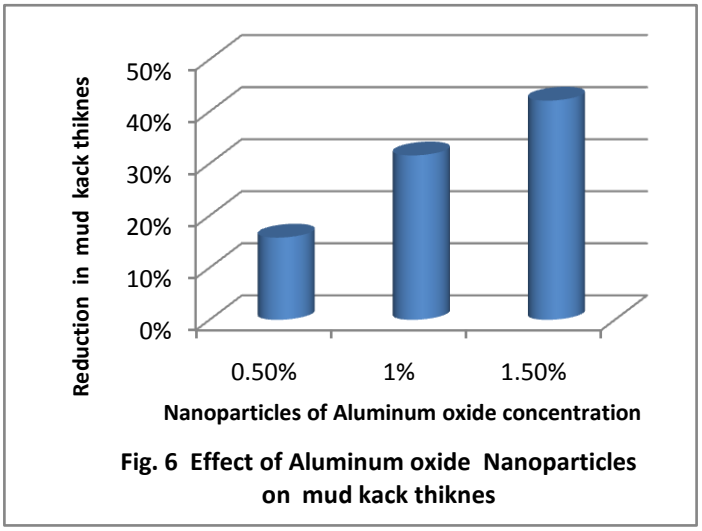

Fig. 6 Effect of Aluminum oxide Nanoparticles on mud kack thiknes

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NOMENCLATURE

XRD	X-ray diffraction
TEM	Transmission Electron Microscopy
EPRI	Egyptian Petroleum Research Institute
LSYP	Low shear yield point
WBM	Water Bas Mud
NAO	Nanoparticles of aluminum oxide
Rpm	Revelation per minute
PV	Plastic Viscosity,
Yp	Yield point

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