Mechanism of Heat Transfer with Nanofluids for the Application in Oil Wells

A.H. Bhat, Imran Khan, Irshad Ul Haq Bhat, H. Soleimani and Mohd Amil Usmani

Abstract Nanofluid plays an important role in a drilling process which includes the removal of cuttings, lubricating, and cooling the drill bits. Nonetheless, production increases from the reservoirs which are non-conventional, and the stability and performance of conventional drilling fluids under high-temperature and high-pressure (HTHP) environment have apprehensiveness. Both water- and oil-based drilling fluids are likely to experience a number of degenerations such as degradation of weighting materials, gelation, and disintegration of polymeric additives under HTHP conditions. Lately, nanotechnology has shown a lot of promise in the oil and gas sectors, including nanoparticle-based drilling fluids. This chapter is focused on to explore the influence of nanoparticles on the heat transfer efficiency of drilling fluids to make the drilling phenomena smooth and cost effective. The chapter begins with explaining the importance of drilling fluid during the drilling process with a historical assessment of drilling fluid industry development. It is followed by definitions, uses, and types of drilling fluid as well as the additives that are appended to enhance drilling fluid performance. Moreover, the progress of the oil production industry from unconventional wells has been discussed after which the limitations and degradation of the traditional drilling fluid have been taken up. Finally, this chapter discusses the great potential of nanotechnology in solving drilling problems in addition to the technical and the economic benefits of using nanomaterials in drilling fluids before offering a brief conclusion.

A.H. Bhat (✉) · H. Soleimani
Department of Fundamental and Applied Sciences, Universiti Teknologi PETRONAS, 32610 Bandar Seri Iskander Perak, Darul Ridzuan, Malaysia
e-mail: aamir.bhat@petronas.com

I. Khan
Department of Chemistry, College of Science, Sultan Qaboos University, P.O. Box 36, P.C. 123 Al-Khod Muscat, Sultanate of Oman

I.U.H. Bhat
Faculty of Earth Science, Universiti Malaysia Kelantan, 17600 Campus Jeli, Kelantan, Malaysia

M.A. Usmani
Department of Chemistry, Eritrea Institute of Technology, P.O. Box 12676, Asmara, Eritrea

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Nomenclature

ODA	Octadecylamine
GONs	Graphene oxide nanosheets
PVP	Polyvinylpyrrolidone
Csf	Empirical coefficient
q''	Heat flux
Pe	Peclet number
Re	Reynolds number
(x/D)	Larger axial distance/pipe diameter
Nu	Nusselt number
HTHP	High temperature and high pressure
OBM	Oil-based mud
WBM	Water-based mud

1 Introduction

The operation of drilling has three operational components that work simultaneously in the boring hole: a rotating system which rotates the drill bit, a lifting system that raises and lowers the drill string into the hole, and a circulating system which performs the function of moving a fluid around from the drill stem, out of the drill bit and up again to the hole at the surface, and this fluid is referred as drilling fluid (Van Dyke 1998). Drilling fluids are important for the success of the process as they enhance oil recovery and decreases the time required to achieve first oil (Nasser et al. 2013). The drilling fluids in the drilling process can be compared with the blood in the human physical body.

The mud pump can be related to the heart; the transfer of the cuttings from the borehole by the drilling fluid represents the unwanted materials that are cleaned from the human body by blood, and the mud cleaning system represents the kidney and lungs. Latest investigations have demonstrated that nanofluids have additional features for applications where heat transfer, drag reduction, binding ability for sand consolidation, gel formation, wettability alteration, and corrosive control are of great interest.

The synthesis of nanofluids is a simple process of addition of nanoparticles in low volumetric quantities to a fluid. The nanoparticles improve the fluid's mechanical, rheological, optical, and thermal characteristics. The nanoparticles may provide the following supports to the fluids: (i) improved stability against sedimentation since surface forces easily balance the gravitational force, (ii) thermal, mechanical, optical, rheological, electrical, and magnetic properties of nanoparticles depend notably on the size and shape, can be fabricated during the manufacturing, and are often more advanced to the base material.

The important parameters for the drilling fluid to be germane are high-temperature transfer and flow properties. Furthermore, it must be ecofriendly in order to perform the functions in an efficient and responsible manner (Wawrzos and Weintritt 2007). Lately, these specifications have been achieved, with some constraints by water-based and oil-based muds. Both water-based and oil-based muds contain bentonite clay and some of the chemical additives (Shah et al. 2010). These chemical additives may amend density, reduce corrosion rate, change viscosity, and ceases bacterial growth. Nonetheless, for the deep well drilling, the conditions of temperatures and pressures are challenging, and the heat transfer demand on the drilling fluid are nearly impossible to meet (Oakley et al. 2000).

Thus, to design a drilling fluid in this situation which has a potential to work efficiently, it is required to notably improve the fluid's thermal properties.

Nanotechnology presents a light, strong, and corrosion-resistant material required for the stake holders in the drilling fluid (Salem and Noah 2014). The application of nanoparticles in the drilling fluids will facilitate the drilling engineers to maintain the rheology of the drilling fluid by modifying the type, composition, or size distribution of nanoparticles in drilling fluid to conform any special situation (Abdo and Haneef 2013). The materials manufactured from nanoparticles are different from those prepared using their larger equivalents. Nanomaterials are stronger and more interactive than other materials and also conduct heat efficiently (Singh et al. 2010). The reason behind that is the increased surface area. For a given amount of material, there are a larger number of particles on account of their size reduction and there is more aspect ratio to bear the heat (Shah et al. 2010).

The nanotechnology has transformed the field of science and engineering due to its incredible range of applications. The oil industries like many industries can be greatly benefited from nanotechnology (Abdo and Haneef 2013). The most encouraging prospect among them is the use of nanoparticles in drilling muds so as to have a better operational performance, stability, and suitability. These features make drilling fluids adopt comprehensively under operating conditions by slight changes in composition and sizes (Ibid). Amanullah and Al-Tahini (2009) define drilling fluids loaded with nanomaterials as mud containing additives with particle sizes between 1 and 100 nm; nanofluids were also classified into simple and advanced nanofluids based on the concentration of the nanoparticles in drilling fluids. Nanoparticles in drilling fluids can play a distinctive role in fixing the most common issues during drilling like wellbore instability, lost circulation, pipe sticking, toxic gases, high torque, and drag.

This chapter discusses the preparatory methods of nanofluids and also throws light on the type of heat transfer capabilities in nanofluids along with mechanism.

2 Nanofluid Preparation

2.1 Two-Step Method

This method is commonly used method for preparing nanofluids. In the very first step, chemical or physical methods are generally applied to produce dry powders of nanoparticles, nanofibers, nanotubes, or other nanomaterials. Next step involves the nanosized powder being dispersed into a fluid with the aid of intensive ultrasonic agitation, magnetic force agitation, high-shear mixing, ball milling, and homogenizing. The two-step method is the most economic method to develop nanofluids in large scale, because nanopowder synthesis techniques have already been scaled up to industrial production levels. On account of high surface area and surface activity, nanoparticles have the proneness to aggregate. To ameliorate the stability of nanoparticles in fluids, use of surfactants is an important technique. However, for high-temperature applications, the functionality of the surfactants under high temperature is a big concern. The disadvantage of two-step method is the preparation of stable nanofluids, and to overcome this difficulty, many advanced techniques are developed to produce nanofluids, including one-step method which is given in detail below.

2.2 One-Step Method

Eastman et al. (2001) introduced a one-step physical vapor condensation method to prepare Cu/ethylene glycol nanofluids in order to minimize the agglomeration of nanoparticles. In this method, preparing and dispersing the particles in the fluid takes place simultaneously. The processes of drying, storage, transportation, and dispersion of nanoparticles are ignored in this method, so the agglomeration of nanoparticles is reduced and the stability of fluids is increased (Li et al. 2009). The preparation of uniformly dispersed and the stably suspended nanoparticles in the base fluid can be easily achieved by this method. Another efficient method to prepare nanofluids using different dielectric liquids is the vacuum-SANSS (submerged arc nanoparticle synthesis system) (Lo et al. 2005a, b). Various thermal conductivity properties of the dielectric liquids can alter and determine the different morphologies of the liquid. Many morphological shapes such as needle, polygonal, square, and circular are exhibited by the prepared nanoparticles in this method. The method avoids the unwanted particle aggregation adequately well.

The synthesis of large-scale nanofluids is not possible by one-step physical method and also the cost is too high, so the one-step chemical method is developing briskly. Novel one-step chemical method was presented by Zhu et al. for preparing copper nanofluids by reducing $CuSO_4 \cdot 5H_2O$ with $NaH_2PO_2 \cdot H_2O$ in a solvent ethylene glycol under the influence of microwave irradiation (Zhu et al. 2004). The uniformly dispersed and stably suspended copper nanofluids were achieved. The same method was used to prepare mineral oil-based nanofluids having silver nanoparticles with a narrow-size distribution (Bönnemann et al. 2005). The particles could be stabilized by Korantin, which coordinated to the silver particle surfaces through two oxygen atoms forming a dense layer around the particles. The silver nanoparticle-based nanofluids were stable for about one month. Also, the microwave-assisted one-step method was used to prepare stable ethanol-based nanofluids containing silver nanoparticles (Singh and Raykar 2008). Polyvinylpyrrolidone (PVP) was employed as the stabilizer of colloidal silver and reducing agent for silver in solution in the method. For the synthesis of silver colloids, the cationic surfactant octadecylamine (ODA) is also an efficient phase-transfer agent (Kumar et al. 2003). The phase transfer of the silver nanoparticles emerges on account of coupling of the silver nanoparticles with the ODA molecules contained in organic phase via either weak covalent interaction or coordination bond formation. For the preparation of homogeneous and stable graphene oxide colloids, phase-transfer method has been developed. Graphene oxide nanosheets (GONs) were favorably transferred from water to *n*-octane after treatment by oleylamine (Yu et al. 2011). However, there are some drawbacks for one-step method. The most critical one is that the residual reactants are left in the nanofluids because of incomplete reaction or stabilization. It is difficult to clear up the nanoparticle effect without eliminating this impurity effect.

2.3 Other Novel Methods

The continuous flow microfluidic microreactor to prepare nanofluids of copper was developed by Wei et al. This method can be used to prepare continuously copper nanofluids, and by adjusting certain factors such as concentration of the reactant, flow rate, and additive, the microstructure and properties of the nanofluid can be changed. A unique precursor transformation method with the aid of ultrasonic and microwave irradiation can prepare CuO nanofluids with high solid volumetric percentage ($\sim$10 vol%) (Zhu et al. 2007). The precursor $Cu(OH)_2$ is converted to CuO nanoparticle in water under the influence of microwave irradiation. The addition of ammonium citrate helps in the prevention of agglomeration and nucleation of nanoparticles, thereby stabilizing CuO nanofluid with enhanced thermal conductivity as compared to the other methods of dispersion. In order to prepare monodisperse colloids of noble metal, phase-transfer method is simply an effortless way to prepare (Chen and Wang 2008). The phase-transfer method was adopted by Feng et al. for synthesizing gold, silver, and platinum nanoparticles on account of the decline of the dissolution of polyvinyl pyrrolidone in water with the increase in the temperature (Feng et al. 2006). The kerosene-based Fe_3O_4 nanofluids is withal prepared by phase-transfer method. The grafting of oleic acid on the surface of ferric oxide nanoparticles has been successfully carried out by the process of chemisorption, thereby rendering ferric oxide nanoparticles to have good consonance with the kerosene (Feng et al. 2006). Since, it was reported earlier that thermal conductivity is a function of time while the same was not found in case of Fe_3O_4 nanofluids synthesized by phase-transfer method. One of the main problem of nanofluids synthesizes is to prepare them with controllable microstructure. The nanofluids characteristics very much depend on the shape and structure of nanoparticles. The latest findings proves that nanofluids prepared by chemical solution method show great deal of enhancement in conductivity and stability as compared to the rest of the methods (Yu et al. 2010). The controllability is the best virtue of this method. Various factors of synthesis such as temperature, acidity, ultrasonic, and microwave irradiation can be controlled.

3 Heat Transfer in Nanofluids

3.1 Thermal and Heat Transfer Characteristics

Thermal conductivity is one of the important characteristic of nanofluids due to its immense theoretical and practical interests to researchers and technical personnel. Various methods has been described by Wu et al. (2009) and Paul et al. (2010) for analyzing the thermal conductivity of nanofluids such as transient hot-wire method (Kostic and Simham 2009; Vadasz 2010; Hong et al. 2011), steady-state parallel plate method (Shalkevich et al. 2010), temperature oscillation method (Das et al. 2003), and 3-u method (Wang et al. 2007). From these methods, the transient hot-wire technique has been largely in use. The mechanism of the hot-wire method relies on the following components: continuous heat generation source, an infinitely long and thin constant line, and blowing the heat into an illimitable test medium. Nanofluids being electrically conductive, it is complex to apply the simple transient hot-wire technique precisely. Nagasaka and Nagashima suggested a modified hot-wire cell and electrical system (Nagasaka and Nagashima 1981) by painting the hot wire with an adhesive made of epoxy resin, which has exceptional properties of electrical insulation and heat conduction. This method is known to be fast and very much precise method (Kostic and Simham 2009).

The most typical and cost-effective nanoparticles frequently used by scientists in their experimental designs include alumina (Al_2O_3) and copper oxide (CuO). These investigations have established that with the increase in the loading percentage of nanoparticles up to a volumetric percentage of 5 %, the thermal conductivity of nanofluids also increases. It is very important to describe here that nanofluids with low loading percentage of nanoparticles are advantageous in order to achieve better dispersion stability which is exclusively necessary for studying the characteristics of nanofluids and their applications (Saidur et al. 2011). In certain cases, the increment in thermal conductivity has been found to be nonlinear with respect to their nanoparticle concentration which shows ambiguity with the classical effective medium theory (EMT) as reported by Singh et al. (2010). The same behavior has also been described by Choi et al. (2001). The nonlinear behavior was first observed in CNTs-based PAO nanocomposites where thermal conductivity increment was found to be nonlinear with loading percentage of nanoparticles. It was further proved by Xie et al. (2003), Wen and Ding (2004), and Shaikh et al. (2007) that CNTs-based nanofluids showed less increment in thermal conductivity as compared to the data by Choi et al. (2001). Strikingly, the same nonlinear behaviors are observed in the nanofluids with spherical nanoparticles reported by Murshed et al. (2005), Hong et al. (2005), and Chopkar et al. (2006).

The research in the last decade proves that the discernible increment in the thermal conductivity of nanofluids depends on many parameters which include type of material, concentration, particle size and shape, basefluid, temperature, and chemical treatments (Eastman et al. 2001; Xie et al. 2002; Liu et al. 2005; Chon et al. 2005; Ding et al. 2006; Wen and Ding 2006; Yang and Han 2006). Mostly, the enhancement in thermal conductivities of nanofluids is due to increase in the loading percentage of nanoparticles (Eastman et al. 2001; Xie et al. 2002; Liu et al. 2005; Chon et al. 2005; Ding et al. 2006), reduced particle size (Xie et al. 2002), and increased temperature (Wen and Ding 2006). The stability due to the dispersion of nanofluids mainly is enhanced with chemical additives, which basically alters the pH values which in turn affects the thermal conductivity (Wen and Ding 2006; Yang and Han 2006; Wang et al. 2009; Meibodi et al. 2010; Kang et al. 2006; Chiesa and Das 2009).

However, the issue of nonlinearity is still to be addressed and needs further attention from the researchers. How to remove the ambiguity between the linear increment of thermal conductivity and that in nonlinear? How to manage the agglomeration or flocculation of nanoparticles, which has been found to be the main contributor for the increased thermal conductivity by some scientists, and to maintain balance between the thermal conductivity and dispersion stability? How to optimize the experimental process in order to standardize the optimal conditions to achieve enhanced thermal conductivity?

3.2 Convective Heat Transfer

The study on the convective and boiling heat transfer of nanofluids as compared to the thermal conductivity is still limited. The heat transfer coefficient for convective heat transfer process depends on many characteristics other than thermal conductivity which includes density, specific heat capacity, and dynamic viscosity of nanofluids. The properties of density and specific heat capacity at low particle loading are close to those specifying the base fluid, and the following theoretical equations were proposed by Pak and Cho (1998) and Xuan and Roetzel (2000), respectively.

$$\rho nf = \rho p\varnothing + \rho nf(1 - \varnothing) \tag{1}$$

$$C_{p,nf} = \frac{\varnothing\rho_p C_{p,p} + (1 - \varnothing)\rho_{bf} C_{p,bf}}{\rho_{nf}} \tag{2}$$

There is limitation in using Eq. (2) both theoretically and experimentally on nanofluids (Vajjha and Das 2012). Lately, some of the scientists have determined the dynamic viscosity of nanofluids. The viscosity of the TiO_2-based water nanofluids has been determined by Murshed et al. (2008), and the same property has been compared with previous studies, and it was observed that the nanofluids show higher viscosities with the increase in the loading percentage of nanoparticles. Nevertheless, in case of Al_2O_3-based water nanofluids, viscosity was found to decrease with the increase in the particle dispersion (Wang et al. 1999). For such ambiguity, further detailed research is required.

For any fluid, heat transfer coefficient is a function of the Nusselt number. The experimentally derived interrelation for the Nusselt number for nanofluids was first reported by Pak and Cho (1998)

$$Nu_{nf} = 0.021 Re_{nf}^{0.8} Pr_{nf}^{0.5} \tag{3}$$

The Peclet number effect of copper-based water nanofluid was reported by Xuan and Li (2003) and Li and Xuan (2002) through the following equations, and this includes the convective heat transfer interrelations for both laminar and turbulent flow of the nanofluids.

$$Nu_{nf} = 0.4328\left(1.0 + 11.285\varnothing^{0.754} Pe_d^{0.218}\right) \underbrace{Re_{nf}^{0.333} Pr_{nf}^{0.4}}_{\text{Laminar flow}} \tag{4}$$

$$Nu_{nf} = 0.0059\left(1.0 + 7.6286\varnothing^{0.6886} Pe_d^{0.001}\right) \underbrace{Re_{nf}^{0.9238} Pr_{nf}^{0.4}}_{\text{Turbulent flow}} \tag{5}$$

Wen and Ding (2004) reported that Reynolds number in the range of 700–2000 shows an increment in the heat transfer coefficient in case of Al_2O_3-based water nanofluids for laminar flow with the increase in the volumetric fraction of particles; likewise, the thermal conductivity was discussed in the previous section. The same researcher reported the increment in heat transfer coefficient in case of MWCNT-based water nanofluid (Ding et al. 2006) for downstream flow with larger ratio of (axial distance, *x,* pipe diameter, *D*). One of the ambiguities with respect to the graphite in transmission fluids or in synthetic oil mixture with *Re* less than 110 for laminar flow is that the heat transfer increment is found to decrease with the increase in the temperature, which is a reverse trend as found in the case of thermal conductivity. However, this observation is weak as the temperature range is too low. Further results are required to establish this trend. The heat transfer increment versus Peclet number in the range of 2000–7000 for laminar flow of Al_2O_3-based water and CuO-based water nanofluids has been reported by Heris et al. (2006). The Nusselt number ratios increase with the increase in Peclet number in two types of fluids with the identical volumetric concentrations but different particle size. For heat transfer increment, it is concluded that particle types and particle size have little effect it.

However, the available literature in most of the cases reports that the heat transfer enhancement could be ameliorated with the dispersion of nanoparticles in the basefluid. The heat transfer increment versus Reynolds number has tendency to be identical in all three forms of nanofluids. The increment in the heat transfer is observed to increase with the volumetric concentration of particles, however; there is no clear influence of Reynolds number on the heat transfer increase. Many researchers have studied the convective heat transfer in nanofluids under non-laminar and laminar flows like Daungthongsuk and Wongwises (2008), Yu et al. (2009), Williams et al. (2008), Rea et al. (2009), He et al. (2007), Sommers and Yerks (2010), Anoop et al. (2009), Daungthongsuk and Wongwises (2007), Mohammed et al. (2011), and Sarkar (2011).

Typically, heat transfer equations for nanofluids were revised from the common equations such as Dittus-Boelter equation (1930) or the Gnielinski equation (1976) with the added factual parameters.

3.3 Boiling Heat Transfer

The process of boiling is basically a change in the phase of liquid to vapor from a heated surface or in a superheated liquid layer near to the hot surface. Normally, pool boiling and forced convective boiling are the two types of boiling process. Generally, very little advancement has been made on flow boiling heat transfer of nanofluids, while pool boiling heat transfer has made substantial progress and will be discussed here in this section. In this kind of process, two main conditions are included: excess temperature (the difference between wall and the liquid saturation temperatures at ambient pressure, $\Delta T = T_w - T_s$) and heat flux (q'') (Murshed et al. 2011). The established research finding reports that the inclusion of solid particles in the conventional base fluid can escalate its boiling heat transfer efficiency (Wen and Ding 2005; Prakash et al. 2007; Soltani et al. 2009; Henderson et al. 2010; Das et al. 2003; Bang and Chang 2005; Rohsenow 1952; Zuber 1959). This is notably due to the difference in the characteristics of nanofluids such as the effect of particle materials, their sizes and concentrations, chemophysical characteristics of basefluid, various types of heaters involved. In the majority of the cases, the inclusion of nanoparticles to the fluid increases the rate of the heat transfer, and the enhancement increases with the increase in the nanoparticle concentration. This result is in complete agreement with the thermal conductivity increment. Further, pool boiling data for heat transfer of alumina particles in water reported by Pioro (1999) and Vassallo et al. (2004) showed that the inclusion of nanoparticles to the base fluid deescalates the rate of heat transfer and the rate decreases further as the particle volumetric concentration increases. Two important interrelations which determine the boiling heat transfer coefficient and critical heat flux include Das et al. (2006) and Keblinski et al. (2002) correlations:

$$\frac{C_p(T_w - T_s)}{h_{fg}} = C_{sf}\left[\frac{q'}{\mu h_{fg}}\sqrt{\frac{\sigma}{g(\rho-\rho g)}}\right]0.33\left(\frac{C_p\mu}{k}\right)n \tag{6}$$

The C_{sf} and exponent n values for different surface–fluid mix can be obtained somewhere (Lee et al. 2010). The CHF correlation proposed from Keblinski et al. (2002) is shown as:

$$q'_{\mathrm{CHF}} = K\rho g^{1/2} h_{fg}[g\sigma(\rho-\rho g)]^{1/4} \tag{7}$$

K as a constant is fixed from 0.138 to 0.157. These two reported equations do not support experimental data well (Sergis and Hardalupas 2011). So, new correlation is needed in order to replace this classical model.

4 Mechanism of Heat Transfer in Nanofluids

The mechanism of the heat transfer increment has many discrepancies and ambiguities in nanofluids, although the experimental studies showed substantial increase. Hence, it is important to understand various mechanisms which contribute to the increment in the thermal properties of nanofluids, and the prime discrepancy has been discussed in this section.

It has been mentioned by Yu et al. (2008) that the vivid increase of heat transfer in nanofluids could not be clarified clearly by the present theories and it is on account of this study being spread over different disciplines such as heat transfer, material science, physics, chemical engineering, and synthetic chemistry. Chandrasekar and Suresh (2009) presented four different reasons for the divergent behavior in thermal conductivity of nanofluids:

1. The probable collisions between the nanoparticles which accounts to Brownian motion of particles within the fluid thereby ameliorating the thermal conductivity by direct transmission of heat between particles.
2. The layering of the liquid at the molecular level especially at the liquid/particle interface: The liquid at the solid interface is more regular than bulk of the liquid. The crystalline materials are expected to possesses enhanced thermal conductivity.
3. It has been understood that transport of heat in crystalline materials is being taking place by phonons as a result of vibrations in the crystal lattice. The nanoparticle agglomeration has a substantial influence on thermal conductivity. However, large agglomeration will cause sedimentation, which results in the deescalation of thermal conductivity. It has been proposed that thermal diffusion

is much higher than the Brownian. Nonetheless, the researchers have only evaluated the cases of stationary nanofluids.

Mostly, the mechanism of heat transport in nanofluids can be divided into static and dynamic mechanisms (Wang and Fan 2010). In case of static mechanisms, nanoparticles are supposed to be without any motion in nanofluids, which contains nanolayer, clustering and percolation, interface heat resistance, and frontal geometry while mechanism based on motion called as dynamic mechanisms presumed to have irregular movement of particles in nanofluids, such as Brownian motion and convection at nanosize level. The statistical theory has explained the controversial heat transfer modes of nanofluids in order to describe the mechanism of increment in the heat transport (Sergis and Hardalupas 2011; Yu et al. 2008; Wang and Fan 2010). Finally, it is obvious that more theoretical discussions are required to decrease the ambiguities and explain the controversies in the increment of heat transfer in nanofluids.

5 Prospective Performances

5.1 Wellbore Instability

Generally, huge amount of money is being spent on the stability of wellbore which normally exist due to the incessant exposure of shale to drilling fluid. The wellbore instability is reported to decrease with the inclusion of nanoparticles (Shah et al. 2010). It has been established that the size of the nanoparticles must be less than the size of the pore throat. Also, particle size should not be greater than one-third of the pore throat in order to form a bridge and plug the pores (Suri and Sharma 2004).

5.2 Lost Circulation

Loss of circulation has been categorized as one of the most prominent drilling problems. Drilling fluids in this case is lost either partially or completely to the formation fluid. Some of the factors which lead to this loss of circulation include naturally fractured surface, crevices, and channels. This issue of loss of circulation leads to the escalation in the expenditure and time needed for drilling to reach the requisite depth. The same issue creates loss of pressure control and problems of safety. Hence, excessive time and endeavor have been used to handle circulation loss with the aid of produced materials or muds. So, on using particles in the range from micro to macro has not proved to be of any solution to the problem. However, use of nanoparticles has shown excellent results by decreasing loss of circulation to a greater extent by enhancing carrying capacity enough to hold the cuttings adequately and maintain the density of drilling fluid and pressure at various operational conditions (Bicerano 2008).

5.3 Pipe Sticking

The sticking of the drill pipe occurs due to the large buildup of the cutting, either by the halt in the circulation of the drilling fluid or by the loss of the filtrate in the wall of the bore well (Palaman et al. 2008). This issue has a major effect on the efficiency of the drilling and well expenditures. Many parameters are affected on the sticking of the pipe which includes drilling fluid rheology. So rheology change can cause sticking of the pipe.

To address this issue, nanofluids have been proposed to play a major concern in recovering the stuck pipe. Nanoparticles-based drilling mud has the potential to depreciate the sticking property of mud cakes by developing a thin film covering the drill pipe that lead to cutting down the pipe sticking issue (Amanullah and Al-Tahini 2009). Further, nanofluids are considered to present distinctive carrying capacity, thereby decreasing the pipe sticking by preventing the wellbore from cuttings.

5.4 Reduction Torque and Drag

The interaction between the drill string and the borehole experiences enhancement in torque and drag difficulties. Less success has been achieved by the use of micro- and macroparticles-based drilling muds on account of which torque and drag issue appears (Wasan and Nikolov 2003). However, the use of nanoparticles provides an appreciable decrease in the friction between the pipe and the borehole. So, nanofluids have the feasibility to make slightly lubricating film in the interface of the wall pipe.

5.5 Toxic Gases

The toxic and corrosive gases such as H_2S can be removed from the drilling fluids by employing nanoparticles. This hydrogen sulfide gas should be removed from the drilling fluids for reducing environmental contamination as well as to look into the matter of the health care of drilling staff and get rid of corrosion of drilling instruments (Singh et al. 2010). It has been observed that the inclusion of 14- to 25-nm ZnO particles into the drilling muds eliminates H_2S gas completely while bulk ZnO eliminates only 2.5 % and is a time-consuming process.

6 Nanomaterials as Drilling Fluid: Its Challenges

Along with the ameliorated drilling fluid performance, the less expensive characteristics of nanomaterial are an exciting feature. This leads to the low consumption of the amount of nanomaterials needed for any applications, because of the high surface area-to-mass ratio of nanoparticles, thereby enhancing their reactivity (Shah et al. 2010). Further, the utilization of nanoparticles in drilling fluids has technical and economic dominance.

Technically, nanofluids are applicable to be utilized in new oil production processes and to transcend tough drilling conditions and operations (Nasser et al. 2013). Economically, the utilization of nanoparticles has three major aspects. The prime one is the use of nanoparticles instead of expensive additives and that depreciates the price of drilling fluids. Further, the utilization of nanofluids as drilling fluids in enhanced oil recovery process by addressing the deep well challenge formations (Abdo and Haneef 2013). Also, high expenditures can be prevented by shortening the non-productive time due to the removal of hurdles.

There are some constraints for applying these conventional drilling fluids instead of the added chemicals in order to improve the drilling fluid efficiency. The important disadvantage of water-based drilling fluids is the ability of WBM to solubilize salts which may produce an unwanted increase in density. Moreover, the WBM is capable of interfering with the flow of gas and oil through porous media. Further constraints of the WBM include promotion of the delamination and dispersion of clays and its inability to drill through water-sensitive shale. Further, the corrosion of iron-based drill pipes by WBM, drill collars and drill bits is a matter of concern. Like water-based mud, use of oil-based drilling (OBD) fluids has constraints such as the cost of the OBM along various lines, as the composition of OBM is very expensive and the high cost of treatment cuttings and disposal of it. Also, OBM is not ecofriendly because of their disposal problem and pollution of the water, pollution of land, and the decimation of the coral reefs. Furthermore; dry gas reservoirs cannot use this type of fluids. Besides, WBM and OBM having limitations, GBM also likely experience a number of constraints. High-pressure production leads to the explosive nature of GBM and is the most common risk as the phase of SBM is a gas. Further, drilling string corrosion is caused by the same type. Also, the SBM cannot be used through water-bearing formations because the cuttings will flock together in these formations; therefore, it is not possible to carry out drilling with the aid of air or gas. Oil well drilling technology has evolved from vertical, horizontal to sub-sea and deep-sea wells. These specific drilling techniques require specialized drilling fluids to fix the issues (Shah et al. 2010). The traditional drilling fluids are suitable for low and medium temperature and pressure conditions.

7 Conclusion

To conclude, drilling fluids have multipurpose use in the drilling process. However, there are issues with lost circulation, pipe sticking, wellbore instability, high torque, and toxic gases, with continuous usage of these fluids with unconventional reservoirs. In the last decades of the twentieth century, the researchers discovered nanotechnology, and nowadays there is pursuit to apply this nanotechnology in the drilling process.

This chapter has elucidated the drilling fluid types, functions, and the idea of adding additives. Further, the deterioration of drilling fluids at high-temperature and high-pressure conditions has been defined. From the literature, it can be implied that nanoparticles can ameliorate drilling fluids due to their stability of the rheological properties at high-pressure and high-temperature conditions. The nano-drilling fluid can bring in great changes in oil and gas drilling industry because it can fulfill the specific needs of new drilling technologies, and it can be effective deep down the well in less time.

One of the main drawbacks in this field of research is that it has not looked into the effect of the sizes and the concentrations of nanoparticles that are generally loaded in the drilling fluids. Accordingly, each issue within the drilling well would require the use of specific sizes and concentrations of nanomaterials. Future work could be borne out in the field of property measurements to establish a better comparative study. The cost feasibility of using nanoparticles in drilling fluids can also be explored.

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