Trans. Phenom. Nano Micro Scales, 5(2): 97-101, Summer and Autumn 2017
DOI: 10.7508/tpnms.2017.02.003

ORIGINAL RESEARCH PAPER

Improvement of Thermal Conductivity Properties of Drilling Fluid by CuO Nanofluid

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Received 28 January 2016; *revised 27 November 2016;* *accepted 29 November 2016;* *available online 10 June 2017*

ABSTRACT: In a recent decade, application of nanofluid as a candidate for heat transfer medium has gaining an increasing attention due to its unique advantages. In the light of its unique advantages, it has been utilized in different industries such as oil and gas industries. In this work aims at improving thermal conductivity of the water-based drilling fluid by using the CuO nanofluid additive. CuO nanoparticle is synthesized by precipitation method and CuO nanofluid was produced to use as an additive to drilling fluid. Scanning electron microscope, x-ray diffraction, dynamic light scatering, sedimentation test and zeta-potential are used to characterize nanoparticle and nanofluid. The result indicated that the size of synthesized nanoparticles and nanofluid were about 4 nm and 34 nm, respectively. Finally CuO nanofluid added into drilling fluid to measure the improvement of drilling fluid thermal conductivity. The result shows that the nanofluid concentration in the range of 0.1 to 0.3 vol% is able to enhance the thermal conductivity of drilling fluid to 29 % and decrease the temperature gradient more than twice compare with the base drilling fluid.

KEYWORDS: *CuO nanoparticle; Nanofluid; Drilling fluid; Thermal conductivity; Temperature gradient*

INTRODUCTION

During the past three decades, a vast number of applications have been proposed for nano based technologies and nanofluids due to their unique advantages such as high ratio of surface to volume. Due to the nature of nanoparticles, they are able to significantly modify the properties of the fluids as they scattered in fluid. One of the important parameters can be extremely modified the fluid properties is thermal conductivity [1].

Drilling fluid is one of the most interested candidates among the different candidates for adding the nanoparticle into fluids. Generally, using additives into drilling fluid provides better conditions for drilling operations and to preserve drilling fluid properties, certain additives should be used. Using nanofluid, which increases heat transfer, would enhance the longevity of the bit and its efficiency [2]. Nanofluids defined as a mixture of nano sized particles suspended in base fluid and usually stabilized by different method as adding surfactants. Respect to the unique advantages of nanoparticles, they have gained an increasingly attention for modifying the different physiochemical properties such as thermal conductivity [3]. In more details, several investigations revealed that adding the nano size particles to fluids led to a significant effect on increasing the thermal conductivity while the pressure drop changed slightly compared to the addition of micro particles into fluid.

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Tel.: +987136133709; Note. This manuscript was submitted on January 28, 2016; approved on November 27, 2016; published online June 10, 2017.

Among different nanoparticles, CuO nanoparticle and nanofluid are the most widely used in various field [4] such as thermal conductivity [5], chemical secsor [6], catalyst [7], biomaterial [8] and etc. In the case of thermal behaviour of materials, enhancement of liquids thermal conductivity is an extremely important topic of the energy efficiency point of view. For this purpose, the researchers concentrate on the application of nanoparticles as a thermal conductivity modifying agent [9, 10]. Lee et al. [4] produced CuO fluid via two steps method using ethylene glycol (EG) as the base fluid. They have reported that addition of CuO nanoparticles with size of 18-24 nm, it is possible to enhance the thermal conductivity about 20 %. Kwak et al. [11] reported that application of CuO nanofluid with 10-30 nm size can enhance the thermal conductivity up to 6 %. Zhang et al. [12] studied the thermal conductivity of water based nanofluid including CuO nanoparticle with size of 33 nm. They have reported that adding CuO nanoparticle increased the thermal conductivity about 20%. Lo et al. [13] synthesized the CuO nanofluid via CC-SANSS method to study the thermal conductivity. The results showed that thermal conductivity increased about 35.99%. Nasiri et al. [14, 15] reported the effect of CNT structures (five different structure) on thermal conductivity and stability of water based nanofluid and showed that the increasing number of nanotube wall, decrease stability and thermal conductivity. In this work, CuO nanoparticle was synthesized by precipitation method. Then CuO nanofluid was produced by two step method. CuO nanoparticle were characterized by

	Nomenclature		
		T	fluid temperature
ΔT	Temprature gradinet		**Greek Symbols**
K	thermal conductivity	*b*	base

dynamic light scatering (DLS), scanning electron microscope (SEM) and X-ray diffraction (XRD). CuO nanofluid were characterized by sedimentation test, dynamic light scatering (DLS) and Zeta-potential. Finally CuO nanofluid was added to the water based drilling fluid and thermal conductivity propertied was mesured. The effect of nanofluid concentration was investigated on the improvement of thermal conductivity properties of water based drilling fluid.

EXPERIMENTAL

Material

Copper acetate ($Cu(CH_3COO)_2$), acetic acid ($C_2H_4O_2$), sodium hydroxide (NaOH), ethylene glycol ($C2H_6O$), ethanol ($C_2H_{62}O$) and cetyltrimethylammonium bromide (CTAB) were purchased from Merck. Bentonite was kindly provided by National Iranian Oil Company, Iran.

The synthesis of CuO nanoparticle

The used CuO nano powder was used in the current study, synthesized in a previous work [16]. A brief description of the used procedure for synthesizing the nanoparticles of copper oxide, 2.7 gr copper acetate and 2 ml acetic acid was mixed with 600 ml ethylene glycol in a round-bottomed flask equipped with a return mechanism. Then, the solution was stirred vigorously with the hot plate stirrer.

The solution was heated up to 78^{o}C and the 40 ml ethylene glycol solution of NaOH 1 M was gradually dropped into the solution under magnetic stirring at 78 °C, until the mixture’s pH reached the value of 6–8, the point at which a great quantity of black precipitation was simultaneously created. Being cooled at room temperature, the precipitation was centrifuged, the unwanted products were removed, CuO nanoparticles were purified and the generated solution was washed several times with absolute ethanol and deionizer water.

Nanofluid Preparation

In the current study, the two-steps method is used to synthesize the CuO nanofluid and water for fluid base. Nanoparticles by different concentration (0.1 to 0.3 vol.%) are added into the fluid base (100 ml) and stirred thoroughly with a magnetic stirrer with 900 rpm. Then, CTAB surfactant are added to mixture. And mixed by magnetic for 1 hr with high speed.

Finally, mixture is transferred into an ultrasonic disruptor and sonicated in frequency of 20 kHz and an output power of 250 W. Figure 1 showes the steps for preparation of CuO nanofluid.

The Preparation of Nanofluid Drilling Fluid

To prepare water based drilling fluid, deionized water (175 ml) and bentonite (10 gr) are mixed with Batch Mixer Hamilton (high Speed). The prepared CuO nanofluid (175ml) with a certain concentration is added to the drilling fluid (first mixture) and mixed by Hamilton stirrer for 15 min in order to uniform the drilling fluid. Nanofluid based fluid drilling with different concentration is prepared separately for thermal conductivity measurement.

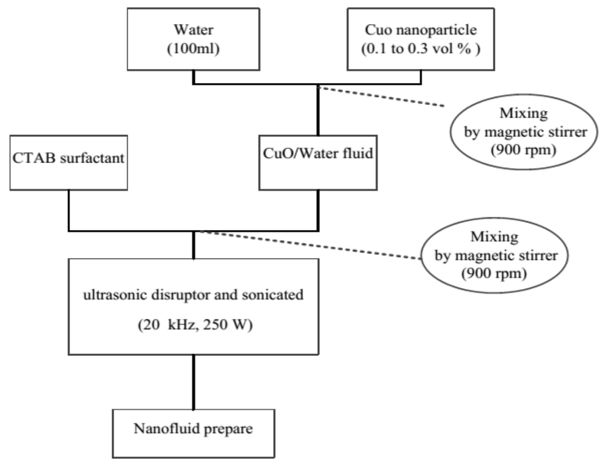

Fig. 1. Schematic of nanofluid preparation

CHARACTERIZATION

CuO nanoparticle was characterized by dynamic light scatering (DLS), scanning electron microscope (SEM) and X-ray diffraction (XRD) and CuO nanofluid with and without CTAB surfactant is characterized by sedimentation test, dynamic light scattering and zeta-potential. The nanoparticle synthesized is analyzed using a Unisantis XMD 300, X-ray diffract meter and systematic Xpert PRO X-ray diffraction (λ=0.17890 nm).

XRD analysis is used to verify the CuO nanoparticle. Dynamic light scatering of CuO nanoparticles and nanofluid is recorded by using a Horiba-LB-550 dynamic light scatering. SEM is a system to determine the morphology and the size of synthesized CuO nanoparticle. Zeta potential of nanofluid was recorded by zeta-check Microtrac.

The drilling fluid heat transfer was measured in a drilling process simulated system in the presence and absence of nanofluid by measuring the difference temperature and the heat transfer coefficient. a heater in a pipe as a drilling bit was considered and drilling fluid surrounded the heater. The difference in temperature between drilling fluid and bit was measured by sensors type K with temperature monitor.

This difference in temperature and heat transfer coefficient in the presence and absence of nanoparticles measured in drilling fluid.

RESULTS AND DISCUSSION

The XRD pattern of nanoparticle synthesized is represented in Figure 2 that is shown the purity of nanoparticle and there is no impurity in XRD pattern of the produced nanoparticle.

The characteristic peaks are 2Θ=35.6 and 2Θ=38.8 for CuO nanostructure.

The broad peaks indicate the nanoparticles average size of 4 nm that is confirmed by Scherrer equation[17].

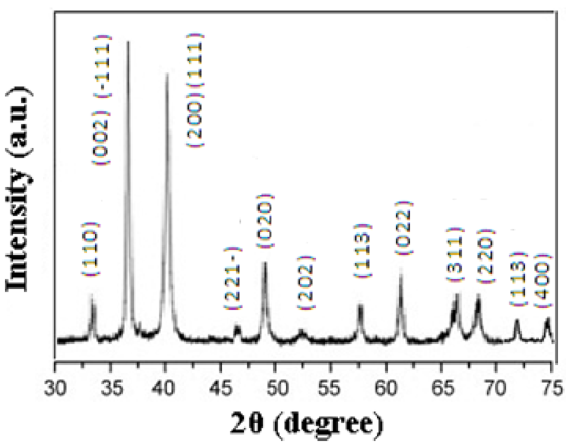

Fig. 2. XRD pattern of CuO nanoparticle

The particle size distribution of CuO nanoparticle is shown in Figure 3, which shows an average particle size of 4 nm.

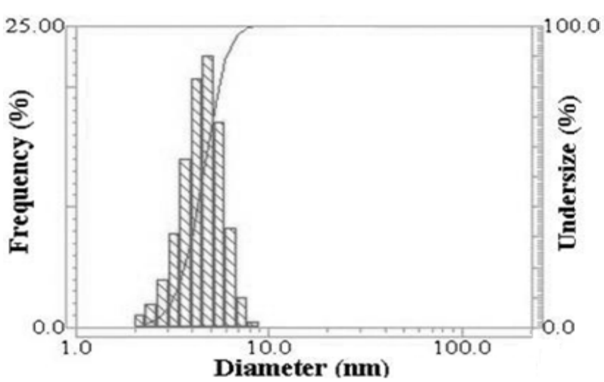

Fig. 3. DLS Image of CuO nanoparticle

The SEM picture of CuO nanoparticles is illustrated in Figure 4. The particles size observed in the SEM picture are in a confine of 3–9 nm and the nanoparticles shape are in a clews-like, According to the XRD model and the Scherrer equation results are in excellent agreement.

Figure 5 shows the sedimentation test of CuO nanofluid samples with maximum concentration in the presence and absence of surfactant.

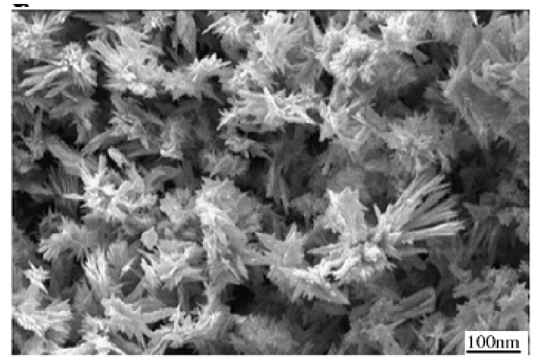

Fig. 4. SEM image of CuO nanoparticle

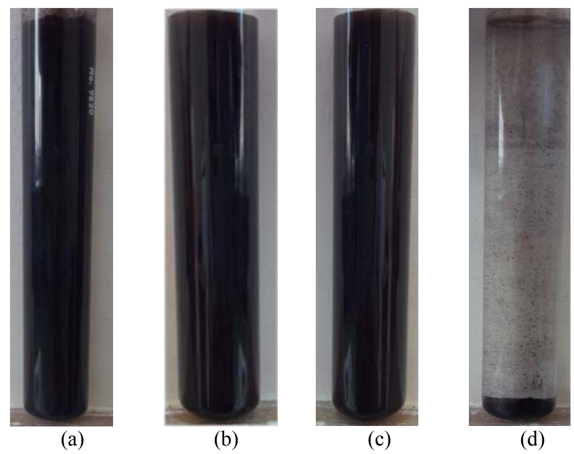

Fig. 5. Sedimentation test of CuO nanofluid a) with surfactant at first time, b) with after 5 days, c) without surfactant at first time and d) without surfactant after 5 days

It is obvious that the nanofluid with surfactant is stable and without it is unstable because of agglomeration of nanoparticle. The zeta-potential analysis is a suitable evidence of this stability. Absoloute zeta-potential for CuO nanofluid with and without surfactant are 56 and 31 mV, respectively. Figure 6 indicates the DLS analysis of two samples of CuO nanofluid in the with and without CTAB surfactant. It reveals that there are apparent differences in the particle size between two samples. The average particle sizes obtained are 2000 nm and 34 nm, with and without CTAB respectively.

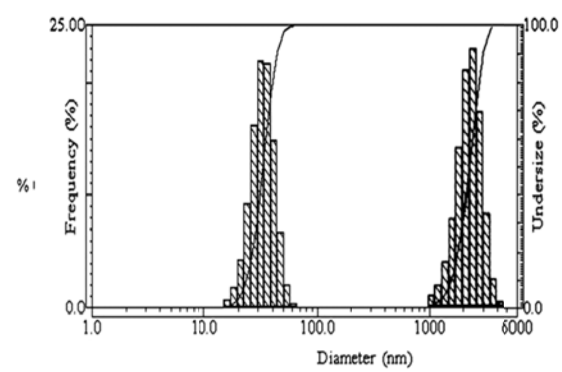

Fig. 6. DLS Image of CuO Nanofluid a) with CTAB Surfactant b) without Surfactant

Therefore the presence of surfactant prevents the agglomeration of nanoparticles also the particle size of nanofluids becomes smaller and finally, the area to volume ratio increases. This increase enhances significantly in the influence of particles in the heat transfer.

Thermal Conductivity of Drilling Fluid

As the temperature increases due to increase in depth in drilling operation, the bit may be damaged significantly because of the accumulation of heat in it. In this condition, drilling fluid plays the role of heat transfer and prevents from heat accumulation in the bit. Therefore, nanofluid is added to drilling fluid to increase its thermal conductivity that results improving in fluid heat transfer. So, the temperature difference and the heat transfer coefficient with a constant heat flux have an inverse relationship are investigated.

The previous findings reveal that a reduction in the temperature difference can significantly increases the heat transfer coefficient. As a result that adding a nanofluid to drilling fluid, leads to decrease in the temperature difference dramatically.

Figure 7 demonstrates temperature gradient of drilling nanofluid versus time.

This Figure can be divided into two stable and unstable parts. Refer to temperature gradient in drilling fluid without nanofluid; it is investigated that it will be taken 5 h to reach the thermal stability condition, which is very longer in compare with drilling base nanofluid. The application of CuO nanofluid into drilling fluid reduces the required time for thermal stability more than twice. This observed modification can be related to this fact that as CuO nanofluid added into drilling fluid, it can penetrated into the structure of drilling fluid and modify its thermal properties. In more details, one can conclude that adding CuO nanofluid can act like a super conductive material in heat transfer and hence causes this reduction. This time reduction is very useful for drilling thermal condition and decreasing thermal stresses inside the reservoir especially for bit.

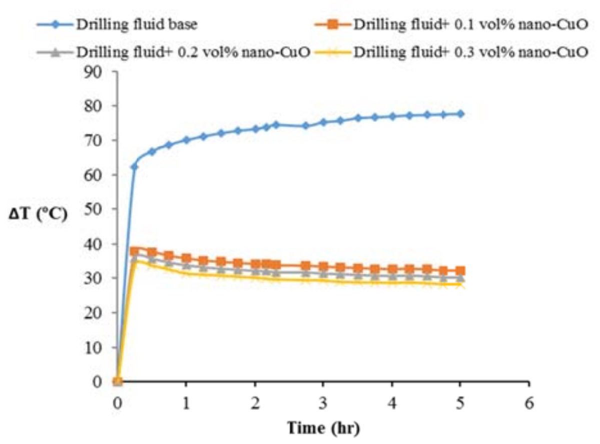

Fig. 7. Variation of temperature gradient versus time for drilling fluid

The effect of adding the nanofluid to drilling fluid on thermal conductivity shows Figure 8.

The nanofluid to drilling fluid increases the thermal conductivity of drilling fluid with nanofluid to without nanofluid (K_{nf}/K_b). It also indicates that an increase in concentration of nanofluid enhances the heat transfer coefficient significantly. According to Figure 7, the effect of increasing the nanofluid concentration on drilling fluid, 0.1vol% to 0.3vol%, the thermal conductivity is enhanced to 29%.

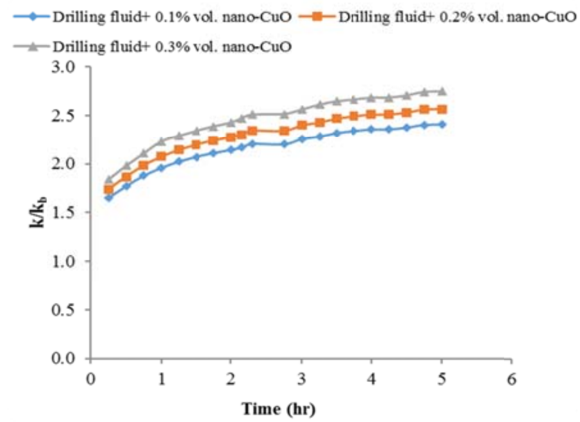

Fig. 8. k/k_b versus time for drilling fluid

In addition, the results indicated in Figure 7, it could be found that the temperature difference of drilling fluid is about 80°C. While with adding nanofluid, this temperature difference decreases to 32 °C. This means that adding nanofluid has this potential to be used as agent for enhancing the driiling fluid thermal conductivity. The point must be mentioned is that increasing the concentration of nanofluid, leads to a reduction in temperature difference, consequently thermal conductivity increases. Actually, this increase in concentration causes to distribute the nanoparticles in drilling fluid, consequently, heat transfer surface increases and thus thermal conductivity will increase. The higher concentration of nanoparticles into nanofluid could affect thermal stability time and reduce it. It means that the time for drilling fluid thermal uniformity is reduced and so it reaches thermal stability in less time.

CONCLUSION

In this study, CuO nanoparticles are synthesized by precipitation method and characterized by XRD, DLS and SEM. The nanoparticle size is about 4 nm. Then nanofluid was produced and characterized by DLS and sedimentation test and zeta-potential. The nanoparticle average size in nanofluid is 34 nm. Finally, the effect of nanofluid to drilling fluid on thermal conductivity and gradient temperature is investigated The obtained results reveal that increasing the nanofluid concentration, enhances the thermal conductivity to 29% and decreases the temperature gradient of drilling fluid containing CuO nanofluid more than twice.

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