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Comparative Study of Impact of Copper (II) oxide and Titanium oxide Nanoparticles on Viscosity of Water Based Drilling Fluid

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ABSTRACT: It is possible to improve the rheology of drilling fluid with the addition of nanoparticles thereby increasing the hydraulic efficiency of drilling campaigns and reducing costs in a variety of reservoir environments. The ability of Copper (II) oxide (CuO) and Titanium oxide (TiO_2) to improve the rheological properties of water based drilling fluid (WBDF) was investigated. Ten laboratory samples of drilling fluids each in different proportion of additives (Xanthan gum, CuO and TiO_2 nanoparticles) were prepared using the standard laboratory barrel (350 ml) method and analysed. Brookfield rotational viscometer was used to determine the rheological properties of the samples and the structural analysis of the interaction between the nanoparticles and the xanthan gum were determined using Fourier Transformation Infra-red (FTIR) spectroscopy. From the results obtained, it can be concluded that CuO and TiO_2 nanoparticle improved the rheological properties of the WBDF but TiO_2 performed a little better than CuO.

KEY WORDS: WBDF, Xanthan gum, copper (II) oxide, Titanium oxide, Nanoparticles, viscosity, FTIR

I. INTRODUCTION

Drilling fluid is an assortment of fluid, basically a mixture of clay, water, minerals and additives. It is pumped through the drill string and continuously introduced to the bottom as it squirts out from the drill nozzles. Drilling fluids provide several functions, some of which includes; removal of the drilled cuttings, lubrication and cooling of the drill bit, controls subsurface pressures, stabilize the exposed rock, provides buoyancy and prevents the contamination of the subsurface formation hydrocarbon fluids. Water-based drilling fluids are among the most popular drilling fluids; thanks in part to their reputation as easy to maintain, economically competitive drilling fluids (Akinyemi and Ogungbade, 2020; Majid and Younis, 2018). Considerable attention has been paid to using nanoparticles to improve the performance of water based drilling fluids in the recent time. Akinyemi and Ogungbade (2020) examined TiO_2/Al_2O_3 nanoparticles effects on water-based drilling fluid properties while Sadeghalvaad and Sabbaghi (2015) examined the effect of the TiO_2/polyacrylamide (PAM) nanocomposite on water-based drilling fluid properties. It was observed from these studies that the nano-enhanced water based drilling fluids increased the rheological properties such as plastic viscosity and yield point. Also, the shear thinning behavior was increased by increasing the concentration of the additive. Sadeghalvaad and Sabbaghi (2015) compared scanning electron microscope (SEM) images obtained from SEM analysis of the pure PAM and the TiO_2/PAM nanocomposite and observed that the TiO_2 grains appeared on the surface and inside of the PAM. Several other researchers also investigated impact of nanoparticles on drilling fluid in various other capacities (Agarwal *et al*, 2011; Sabori *et al.*, 2012; Hoelscher, 2012; Ismail *et al.*, 2016; Salih *et al.*, 2016; Akinyemi and Alausa, 2020; Akinyemi and Kadiri 2020). To establish and control the rheological properties of drilling fluid, water based drilling fluid often contains viscosifying agents such as starches, polyacrylates, xanthan gums and a wide variety of synthetic and natural polymers.

However, if there is a breakdown in the rheology of a drilling fluid, it will be unable to suspend solid dispersed within it such as the weighting or bridging agent or even the drill cuttings which can lead to severe problems. Some of the likely severe problems are settlement, loss in fluid density and possibly a blowout of the well.

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The use of copper (II) oxide and Titanium oxide nanoparticles to improve the rheological properties such as viscosity etc. of water-based drilling fluids is essential in a drilling process, so as to ensure the drilling fluid have correct heat transfer and fluid flow characteristics to work effectively. In addition, application of nanoparticles to formulate high performance drilling fluids has the potential to overcome current as well as future technical challenges encountered by the drilling industry. Hence, in this study, the impact of combination of xanthan gum and nanoparticles of copper (II) oxide and titanium oxide in different ratio on viscosities of WBDFs were investigated. Fourier transform infra-red (FTIR) analysis was used to investigate the interactions of the structures of the xanthan gum with the nanoparticles in different proportions. This study is a follow-up to the previous work carried out the research team.

II. METHODOLOGY

Analytical grade materials with high purity were used in this study. The bentonite clay used was obtained from standard Nigerian chemicals organization. Xanthan gum, copper (II) oxide and Titanium oxide nanoparticles are products of Sigma-Aldrich. Major pieces of equipment used in the study were Brook-field rotational viscometer (Ndj-8S) and Fourier Transform Infra-red (FTIR) spectrometer (Agilent; range: 4000-650 cm^{-1}).

The samples were prepared following the procedure described by Akinyemi and Ogungbade (2020). The first sample of the water based drilling fluid was prepared with water and bentonite clay. 350ml of water was measured using a measuring cylinder and was put in a 500ml beaker. 15 grams of Bentonite clay was weighed using weigh balance and was poured into the beaker containing 350ml of water. A magnetic stirrer was used to mix the 15g of bentonite clay and 350ml of water for 10mins.

The second sample prepared was made up of water, bentonite clay and xanthan gum.

a) 350ml of water and 15g of bentonite clay was stirred for 10 minutes in a beaker using a magnetic stirrer. 1g of xanthan gum was added and mixed thoroughly for 15 minutes using a magnetic stirrer.
b) Similar preparation as in (a) but with 1.5g of xanthan gum was made and mixed thoroughly for 15mins using a magnetic stirrer.
c) Similar preparation as in (a) but with 2.0g of xanthan gum was made and mixed thoroughly for 15mins using a magnetic stirrer.

The third sample of water based drilling fluid was made up of water, bentonite clay, xanthan gum and copper (II) oxide nanoparticle.

a) 350ml of tap water was mixed with 15g of bentonite clay in water in a beaker. This solution was mixed for 20 minutes. 1.0g of xanthan was weighed and added to the solution and was mixed for 20 minutes. 1.0g of copper (II) oxide was weighed, added to the solution and mixed thoroughly for 20 minutes.
b) Similar preparation as in (a) but with 1.5g of xanthan gum and 0.5g copper (II) oxide nanoparticles was made and mixed thoroughly for 20mintes using a magnetic stirrer.
c) Similar preparation as in (a) but with 0.5g of xanthan gum and 1.5g copper (II) oxide nanoparticles was made and mixed thoroughly for 20mintes using a magnetic stirrer.

The fourth water based drilling fluid sample was made up of water, bentonite clay, xanthan gum and titanium oxide nanoparticle. A measuring cylinder was used to measure 350ml of water. 15g of bentonite clay was weighed using weigh balance. Different proportions of xanthan gum and titanium Oxide were used for this experiment.

a) 350ml of tap water was mixed with 15g of bentonite clay in water in a beaker. This solution was mixed for 20 minutes. 1.0g of xanthan was weighed and added to the solution, it was mixed for 20 minutes. 1.0g of titanium Oxide was weighed, added to the solution and mixed thoroughly for 20 minutes.
b) Similar preparation as in (a) but with 1.5g of xanthan gum and 0.5g titanium oxide nanoparticles was made and mixed thoroughly for 20mintes using a magnetic stirrer.
c) Similar preparation as in (a) but with 0.5g of xanthan gum and 1.5g titanium oxide nanoparticles was made and mixed thoroughly for 20mintes using a magnetic stirrer.

The viscosities of the prepared water based drilling fluid samples were determined using Brookfield (Ndj-8S digital) viscometer with measuring range of 20-2,000,000mPa.s, rotational speeds (rpm) of 0.3, 0.6, 1.5, 3, 6, 12, 30, 60 (i.e. eight adjustable speeds), various spindles (code L1, L2, L3, L4) and a LCD screen display to display the viscosity, speed, torque, spindle and maximum viscosity can be measured in the current spindle speed value.

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The prepared solution of drilling fluid is poured into a beaker and placed under the viscometer. A spindle that suits the sample is used and knotted tight at the joint under the viscometer. The viscometer is then adjusted at the knob to the bottom to make the spindle enter the sample placed, the knob is stopped when the "stop-point mark" on the spindle is no longer visible as this indicates that the spindle is well inserted into the solution. The viscometer is powered on, the speed is picked by pressing a button that reads "speed" on it, it is pressed number of times till the speed used is picked, the thermometer from the viscometer is then inserted into the solution/sample to be examined, the spindle used is selected (i.e. spindle 1, 2, 3 or 4). After all these selections, the run viscometer shows the viscosity value button is pressed and the**,** the temperature of the sample, the speed and spindle used. Before another reading is taken, the spindle is removed, washed using distilled water and cleaned using a clean cloth (Akinyemi and Ogungbade, 2020).

Samples 2A, 2B, 2C, 3A, 3B, 4A, 4B used spindle 3 as a result of the obvious thickness in the fluid, in the study. The thermometer was inserted into the solution which displayed the room temperature 31.5^{o}C and a speed of 30 rpm was inputted into the viscometer. The run button was pressed and the value displayed by the viscometer was recorded.

Furthermore, another analysis was done with a speed of 60 rpm for these samples and the readings were recorded. Samples 2A, 2B, 2C, 3A, 3B, 4A, 4B were heated with the use of heating mantles to a temperature of 40^{o}C, these heated samples were taken to the viscometer, using spindle 3 and at a speed of 30 rpm, and the viscosity was recorded. Another reading using spindle 3 and at a speed of 60 rpm was recorded from the viscometer.

These samples were heated again using a heating mantle to a temperature of 40^{o}C. These heated samples were taken to the viscometer, using spindle 3 and at different speeds of 30 and 60 rpm, each viscosity value was recorded for each sample.

Sample 1, 3C and 4C used spindle 2 because of their less-thick nature. They were done differently and each of them was poured into a beaker. The thermometer was inserted into the solution and a speed of 30 and 60 rpm were used and two values of viscosity were recorded for each of these samples at 31.5^{o}C (room temperature). These samples were heated using a heating mantle and were heated to 40^{o}C. The same procedure was used to record the two values for viscosity of each sample. These samples were heated to 45^{o}C and the same procedure was used to record the two values of viscosity of each sample at this temperature.

The FTIR equipment was used to carry out structure analysis of all the additives and their blends in different ratios in order to evaluate how the structures of the additives affected the properties of the drilling fluids samples. The additives were categorized into samples A to G as follows:
Sample A: 1 g copper(II) oxide
Sample B: 1 g xanthan gum
Sample C: 1 g titanium oxide
Sample D: 1 g xanthan gum + 1 g copper (II) oxide
Sample E: 1.5 g xanthan gum + 0.5 g copper (II) oxide
Sample F: 1 g xanthan gum + 1 g titanium oxide
Sample G: 1.5 g xanthan gum + 0.5 g titanium oxide

The Fourier transform infra-red analysis was done at the central laboratory of Yaba College of Technology, Lagos, Nigeria. FTIR uses an infrared (IR) light source to pass through the sample and onto a detector, which precisely measures the amount of light absorbed by the sample. The absorbance creates a unique spectral fingerprint that is used to identify the molecular structure of the sample and determine the exact quantity of a particular compound in a mixture. Infrared radiation for the samples and the result plotted on a graph of transmittance against wavelength were obtained using the Agilent Fourier transform infra-red spectroscope (range: 4000-650).

III. EXPERIMENTAL RESULTS

From the results obtained, the viscosity of water based drilling fluid with increase in xanthan gum concentration at every given temperature (Figure 1). This implies that the xanthan gum acted as a viscosifier which is in agreement with findings of previous researchers (Akinyemi and Ogungbade 2020; Al-Yasira *et al.*, 2019). However, addition of TiO_2

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nanoparticles and xanthan gum in ratio 1:3 (0.5 g TiO_2 and 1.5 g xanthan gum) increased the viscosity of the WBDF more appreciably. It gave the highest increment of the viscosity of all the samples of xanthan gum mixed nanoparticles tested at any given temperature (Figure 1). The next proportion of mixture that gave appreciable increment in viscosity to the WBDF was the mixture of CuO and xanthan gum in ration 1:3 (0.5 g CuO and 1.5 g xanthan gum) followed by the WDBF containing mixture 2g xanthan gum without any nano particles. Thus, TiO_2 nanoparticles improved the rheological property of the water based drilling fluid more than the CuO when mixed with the xanthan gum in the same ratio (ratio 1:3). Addition of either of the TiO_2 or CuO in equal proportion with the xanthan gum to the WBDF did not even increase the viscosity of the drilling fluid as much as 1.5g xanthan gum could do. Hence, addition of either of the two nanoparticles beyond ratio 1:3 could be reducing the viscosity of the drilling fluid rather than increasing it. Therefore, the CuO and TiO_2 nanoparticles could improve the viscosity of water based drilling fluid when applied in little quantity in the presence of xanthan gum. This is in agreement with the findings of previous researchers (Akinyemi and Kadiri 2020; Akinyemi and Ogungbade, 2020). The positive impacts of the nanoparticles on the viscosities of the drilling fluid when added in little quantity may have been due to interaction between the molecules of the xanthan gum and those of the nanoparticles (Akinyemi and Alausa 2020).

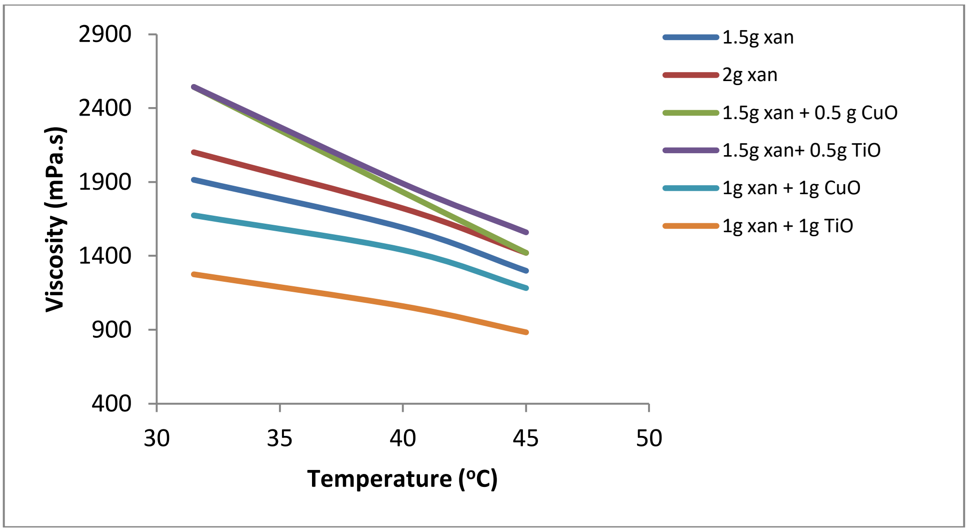

Fig 1. Viscosity against temperature at 30 rpm for drilling fluid containing bentonite, xanthan, copper (II) oxide and titanium oxide in different concentration

Furthermore, from Figure 1, it was observed that the viscosity of the drilling fluid generally reduces as the temperature increases. This is in agreements with finding of previous researchers (Sedaghatzadeh *et al.*, 2012; Akinyemi and Kadiri, 2020). It was observed from Figure 2 that the viscosity of the water based drilling fluid with or without TiO_2 decreases with increase in share rate at any given temperature. This implies that the drilling fluids produced are non- Newtonian and it is shear thinning. It was observed that the WDBF containing 0.5g TiO_2 nanoparticles and 1.5g xanthan gum exhibited the highest viscosity among the samples tested with different proportions of TiO_2 and xantahn gum at any given share rate (Figure 2). However, addition of more TiO_2 nanoparticles above 0.5 g without corresponding addition of xanthan gum resulted in reduction of the viscosity of the drilling fluid (Figure 2). Thus, the optimum proportion of TiO_2 nanoparticles to xanthan gum in the water based drilling fluid may be regarded as ratio 1:3.

It is pertinent to note that the bands at 3418.0 cm^{-1} indicate the presence of a stretching of strong hydroxyl groups, and bands 3354.6 cm^{-1}, 3291.2 cm^{-1} and 2877.5 cm^{-1} indicates O-H functional group (Figures 3). The band at 1714.6 cm^{-1} is assigned to carbonyl group C=O stretching, 1599.0 cm^{-1} indicates C-C (ring) stretch, 1401.5 cm^{-1} indicates C-C (ring) stretch (Figure 3). The band at 1367.9 cm^{-1} is assigned to –C-H bending. Furthermore, the band at 1244.9 cm^{-1} corresponds to C-O stretching, 1155.5 cm^{-1} indicates C-O stretch, the band at 1017.6 cm^{-1} represents C-OR stretching,

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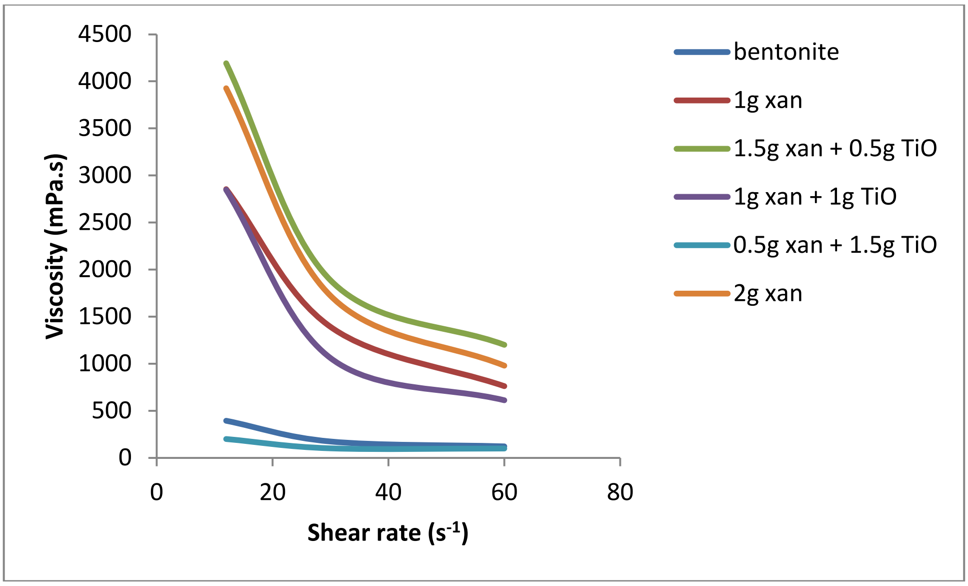

Fig. 2 Viscosity against shear rate of drilling fluid for different concentration of xanthan gum and TiO_2 nanoparticle at 40°C

and the band at 786.5cm^{-1} is assigned to aromatic group C-H. These observations are in agreement with the finding of previous researchers (Akinyemi and Ogungbade 2020; Akinyemi and Kadiri 2020; Al-Yasiri *et al.*, 2019).

From the structural analysis of the blend of the nanoparticles with xanthan gum using FTIR, it was observed that TiO_2 nanoparticles blended with the xanthan gum in ratio 1:3 yielded more interactions of bonds than other proportions of nanoparticles/xanthan gum mixture in this study as revealed in Figures 3 to 5. Twelve peaks/bands were observed in

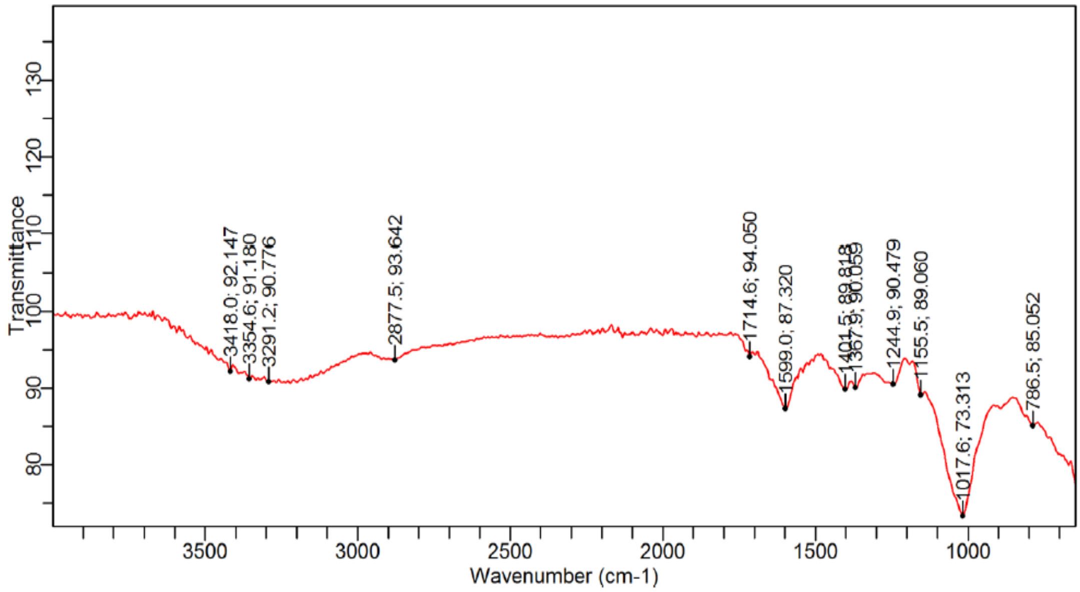

Fig. 3 FTIR spectrum for xanthan gum

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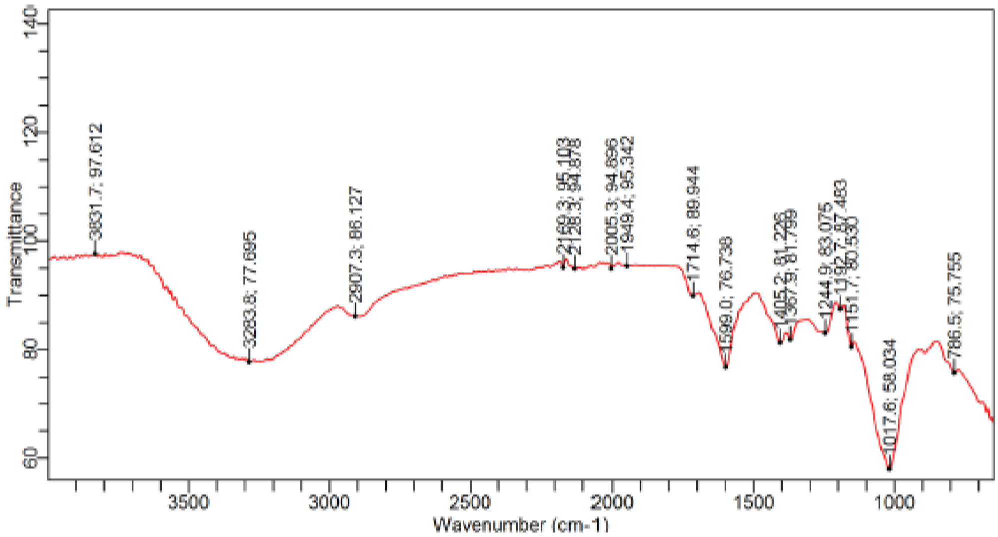

Fig. 4 Spectrum of 1.5 g xanthan gum blend with 0.5 g of copper (II) oxide nanoparticles

WBDF containing xanthan gum without any nanoparticles as shown in Figure 3 while some of these 12 peaks/bands disappeared in the spectra of WBDF containing mixture of the xanthan gum and TiO_2 in ratio 1:3 (Figures 5). This disappearance implies that there were some interaction between the xanthan gum and the TiO_2 nanoparticles. The blend of TiO_2 nanoparticles and xanthan gum in ratio 1:3 revealed nine (9) peaks/bands with new peaks/bands as shown in Figure 5 while that of blend of CuO and xanthan gum in ratio 1:3 revealed sixteen (16) peaks/bands. In both cases there were disappearances of some peak/bands present in the pure xanthan gum spectrum when the xanthan gum was mixed with the nanoparticles.

Peaks/bands above 1714.6 cm^{-1} present in pure xanthan gum spectrum were not found in spectra of xanthan gum mixed with either TiO_2 or CuO nanoparticles. These were replaced with new peaks/bands in some cases having values close to initial ones in pure xanthan gum. These are further indications that there were interactions between the nanoparticles and the xanthan gum. Furthermore, it was observed that six (6) of the peaks/bands in pure xanthan gum were repeated

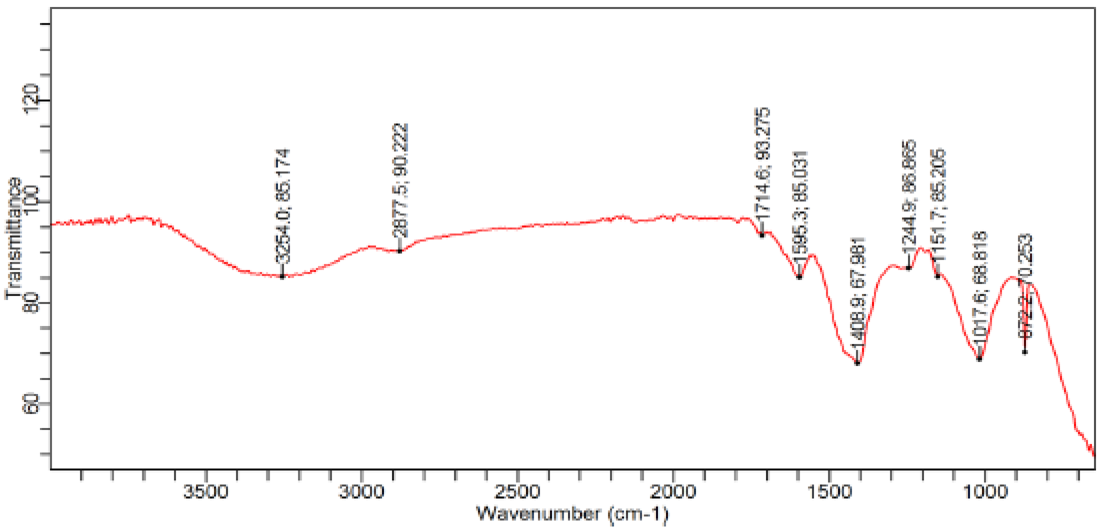

Fig. 5 Spectrum of 1.5 g xanthan gum blend with 0.5 g of titanium oxide nanoparticles

in spectrum of CuO nanoparticles mixed with xanthan gum (1714.6 cm^{-1}, 1599.0 cm^{-1}, 1367.9 cm^{-1}, 1244.9 cm^{-1}, 1017.6 cm^{-1} and 7886.5 cm^{-1}), comparing Figures3 and 4 while only three were repeated in spectrum of TiO_2 mixed with xanthan gum (1714.6 cm^{-1}, 1244.9 cm^{-1} and 1017.6 cm^{-1}) comparing Figures 3 and 5. This may have contributed to the reason while addition of TiO_2 nanoparticles with xanthan gum in ratio 1:3 perform a little better addition of CuO nanoparticles of the same ration in increasing the viscosity of the water based drilling fluid.

IV. CONCLUSION AND FUTURE WORK

From the result obtained in this study, it is concluded that the rheological properties of water based drilling fluid improved with the addition of copper (II) oxide and titanium nanoparticles. For 1.5 g xanthan blended with 0.5 g CuO (ratio 3: 1) and 1.5 g xanthan blended with 0.5 g TiO_2 nanoparticles the viscosity of the drilling fluid improved above when 2 g of xanthan only was used as additive to the water based drilling fluid. The improvement by TiO_2 was better than that of CuO while at some other temperatures for the same ratio of mixture with xanthan gum. The structures of the TiO_2 nanoparticle interacted better with the additive than CuO nanoparticle at 1:3 ratio of mixture with xanthan gum. The results of this study indicate that the bonds between nanoparticles and xanthan gum help rheological properties of the drilling fluids. Thus, for optimal improvement in rheological properties of water based drilling fluid, either TiO_2 nanoparticles or CuO nanoparticles combined with xanthan gum could be used in the oil and gas industry.

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