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Effect of Chemical Additives and Nanoparticles on Rheological Properties of Nigeria Waxy Crude Oil

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ABSTRACT
The uttermost issue in crude oil production and transportation in Nigeria has been identified as solid assemblages of paraffin in pipeline interiors used for production and transit contain wax, more on the surface of production machinery. The main objective of this study was to determine the impacts of some chemical additives and nanoparticles on waxy crude oil obtained from the Niger Delta region of Nigeria. To achieve this objective two crude oil samples were used for the analysis. Viscosity of the crude oil samples were study using a Brookfield NDJ-5S viscometer with addition of the chemical additives (xylene, castor sseed oil (CSO), aluminium oxide nanoparticles, zinc oxide nanoparticles) in concentration of 0.1, 0.2%, 0.3% and 0.4%. The hydrocarbon composition was determined using gas chromatography with flame ionization detector, while the pour point of the samples were determined using ASTM D97. The results obtained the Al_2O_3 and ZnO nanoparticles could depress the pour points of the two samples considered and reduce the viscosity appreciably as the CSO and xylene though in with higher concentration. The ZnO nanoparticles performed better than the Al_2O_3 nanoparticles and could depress the pour point of one of the waxy crude oil from 17ºC to 10 ºC. It is recommended that ZnO should be considered for use as pour depressant or as blend with suitable chemical in the formulation of effective pour point depressant.
Keywords: *chemical additives, alluinium oxide, zinc oxide, nanoparticles, rheological properties*

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I. Introduction

Paraffin wax, Hydrate, and asphaltenes are the three most prevalent and well-known organic solid deposits that impact fluid flow assurance, however during production, scale and sand might potentially pose a major threat (Akinyemi et al., 2016; 2005; Ahmed, 2007). The difficulty with waxy crude oil has an impact on both production rates and, as a result, production economics. The deposition of organic components from waxy crude oil due to the wax precipitating and crystallizing at low temperatures is one of the issues. The existence of high paraffin wax concentration is one of the most common concerns with unconventional oils (Lira-Galeana and Hammami 2000). When the temperature of bulk oil falls below the temperature at which wax occurs, wax precipitation and deposition on the walls of production pipelines begin. When moving through the subsea zone, where temperatures at the bottom can drop as low as 5°C on average, liquid-phase waxy crude oil undergoes three phase shifts (Chala et al. 2018). The wax particles gather within the cluster as the operating conditions (temperature and/or pressure) vary (Ganeeva et al. 2016). The wax precipitates when the clusters are large enough. Wax molecules constantly deposit during the last phase, which is the gelation of a wax layer one on top of the other until a clogged gel forms that may force production pipeline systems to stop working entirely. Controlling wax precipitation and deposition in the oil and gas sector has thus grown to be a significant issue. Among the fundamentals variables that impact the formation of wax deposition are the rheological properties of the wax bearing crude oil (Akinyemi et al, 2016; Adewusi, 1997; Taiwo, Fasesan, & Akinyemi, 2009). For dealing with wax precipitation and deposition, various theoretical and practical methods have been proposed.

Previous researchers had shown that chemical methods are the most convenient and economic way for the prevention of precipitation of the wax from waxy crude oil as well as they increase its flow ability at lower temperature (Deshmukh& Bharambhe, 2008; Mahto et al, 2010; Popoola et al., 2015; Soni & Bharambe, 2006). Some chemicals like xylene, castor seed oil and others have been investigated in past as wax deposition inhibitors (Akinyemi et al, 2018; Akinyemi et al., 2016; Bello et al., 2005). In this study, nanoparticles were investigated to deterimine their impacts on the rheological properties of waxy crude oil. The nanoparticles considered in this study are aluminium oxide (Al_2O_3) and zinc oxide (ZnO). The xylene and castor seed oil were examined along side with the nanoparticles to compare their performances in improving the rheological properties of the waxy crude oil.

II. Materials and Methods

2.1 Materials

The Castor seed oil was purchased from vendors at market in Epe, Lagos State-Nigeria. (xylene) used was analytical grade products of BDH Chemical Ltd, Poole England. The crude oil samples were obtained through the Nigeria Upstream Petroleum Regulatory Commission from major oil companies in the Niger Delta region of Nigeria.

The rheological property of the waxy crude oil at different temperature was measured using Brooke field viscometer. The viscometer is a Ndj-5S Brookfield viscometer with measuring range of 20 - 200,000mPa.s and rotational speeds (rpm) of 6, 12, 30, 60 (i.e. four adjustable speeds).

2.2 Methods

2.2.1 Sample preparation

The crude oil samples were reconditioned by heating them to a temperature of about 60^oC for nearly 10h, with hand-rocking occasionally during heating in the laboratory prior to experiments to erase any previous history that might exist in such samples. Reconditioning the samples ensured that all pre-crystallized wax got re-dissolved into the oil, thereby erasing any thermal and shear history and producing homogenous samples for testing.

2.2.2 Characterization of crude oil samples

The crude oil samples were characterised to determine their hydrocarbon composition were determined using Agilent Technologies 6890N gas chromato-graph equipped with a flame ionization detector (FID) as described by [Akinyemi et al., 2016]. The American Petroleum Institute gravity (APIg) and pour point of the crude oil samples were determined using ASTM D97 and ASTM D287 standard methods respectively. Brook-field rotational viscometer (Ndj-5S) was used to determine the viscosity of the crude oil sample at 30^oC.

2.2.3 Viscosities of samples with and without chemical additives

The prepared crude oil sample at room temperature of 30^oC was poured into a beaker and placed under the viscometer. A spindle that suits the sample was used and knotted tight at the joint under the viscometer. The viscometer was then adjusted at the knob to the bottom to make the spindle enter the crude oil sample placed; the knob was stopped when the "stop-point mark" on the spindle was no longer visible as this indicates that the spindle was well inserted into the crude oil sample. The viscometer was powered on and the speed was picked by pressing a button that reads "speed". The thermometer from the viscometer is then inserted into the sample to be examined, the spindle used was selected (i.e. spindle 1, 2, 3 or 4). After all these selections, the run button was pressed and the viscometer displayed the viscosity value, the speed and spindle used after the run. These values were recorded. Before another reading, the spindle was removed, washed using distilled water and cleaned using a clean cloth.

The procedure was repeated for pure crude oil sample at temperatures of 40^oC, 50^oC, 60^oC and 70^oC. Afterward, the procedure was repeated for crude oil sample with xylene chemical additive at concentrations of 0.1% v/v, 0.2% v/v, 0.3% v/v and 0.4% v/v and the data recorded. Same procedure was repeated for castor seed oil, Al_2O_3 and ZnO in the same concentrations of 0.1% v/v, 0.2% v/v, 0.3% v/v and 0.4% v/v for each chemical additive. The entire process was repeated for the second crude oil sample.

2.2.4 Pour points of crude oil samples with and without chemical additives

The pour point of the crude sample was determined with and without chemical additive using ASTM D97 standard method. Each of the chemical additives (xylene, castor seed oil, Al_2O_3 and ZnO) were added to the crude oil samples in the concentration of 0.1% v/v, 0.2% v/v, 0.3% v/v and 0.4% v/v. The pour points were recorded for the pure crude oil samples and doped crude oil samples at these concentrations.

III. Results

3.1 Results on Characterisation of crude oils samples

From result of hydrocarbon composition analysis shown in Figure 1, pentatriacontane ($C_{35}H_{72}$) has the highest composition (34.5%) in sample A follow by heptatriacontane ($C_{37}H_{76}$) 19.85%. Sample A contains compounds from (C_{18}-C_{38}) which exist as solid, this indicates Sample A crude will deposit much wax because it contains majorly solid. It was observed from Figure 2 that sample B has the highest composition of hydrocarbon of (11.29%) nonane (C_9H_{20}). Nonane has the highest composition of paraffins in the sample while tricosane ($C_{23}H_{48}$) has the least composition (0.06%). Sample B contains paraffin compounds of $C1_8$-C_{26} in higher percentage composition when compared sample A.

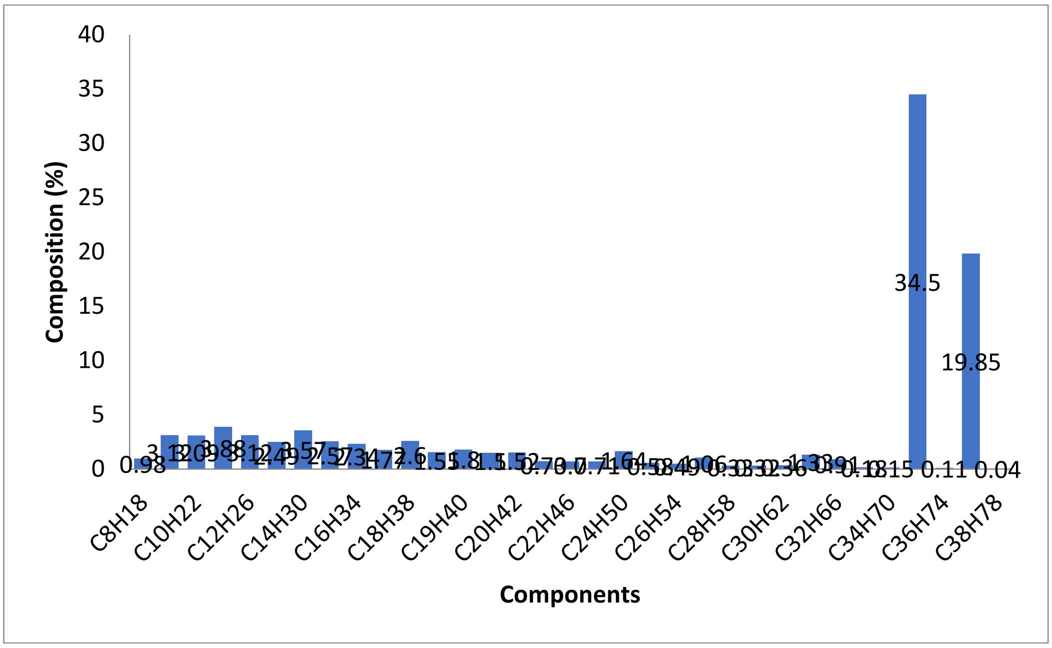

Figure 1: Aliphatic hydrocarbon analysis on sample A

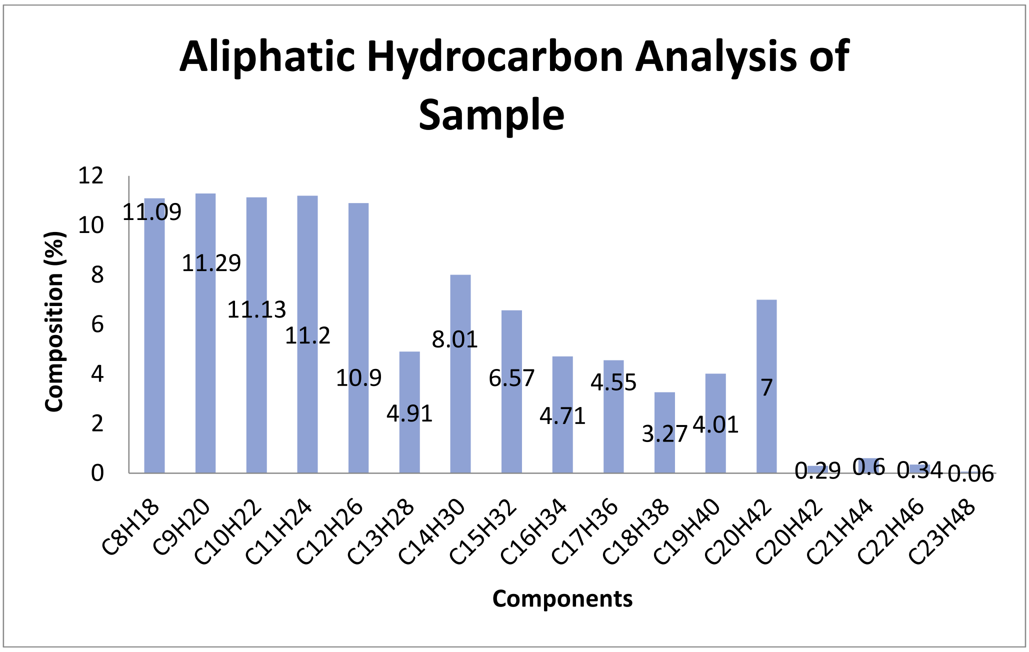

Figure 2: Aliphatic hydrocarbon analysis on sample B

From Table 1, the results of the determination of the characteristic properties of the crude oil samples showed that sample A is lighter than sample B with sample A having the APIg of 31.5 (Table 1). This is in agreement with the previous results obtained in the hydrocarbon analysis in Figures 1 and 2. However, the pour point and viscosity of sample B are higher than those of sample A.

Table 1 Characteristic properties of crude oil samples

Parameter	**Sample A**	**Sample B**
Viscosity, mPa.s at 30°C	197.05	217.15
APIg	31.5	26.8
Pour point, °C	17	22
Wax content (%)	27.38	31.5

3.2 Effects of the Chemical additives on rheological properties of crude oil samples

The result obtained revealed that all the chemical additives had ability to reduce the viscosity of the two crude oil samples (Figures 3 to 8). It was observed that the castor seed oil reduced the viscosity slightly more than the xylene for sample A as shown by Figure 3 both for 0.1% and 0.2% concentration and for sample B as shown in Figure 4. The Al_2O_3 nanoparticles reduced the viscosity of sample A as the concentration increased in the crude oil sample (Figure 5). The Al_2O_3 nanoparticles also reduced the viscosity of the crude oil sample B as its concentration in the sample increased (Figure 6). Similarly it was observed that viscosity of sample A decreased with increase in concentration of ZnO nanoparticles (Figure 7), just viscosity of sample B also decreased with increase in concentration of ZnO in it (Figure 8). It was observed that though the CSO reduced the viscosity of sample A with 0.1% concentration more than the other three chemical additives, at higher concentration of 0.4% the Al_2O_3 and ZnO nanoparticles reduced the viscosity of crude oil sample at par with the CSO, especially at low shear rate of $20.4s^{-1}$ and below (Figure 9). The two nanoparticles with concentration 0.4% reduced the viscosity of sample B more than the 0.1% concentration of xylene and CSO with the ZnO performing better than the Al_2O_3 (Figure 10). .

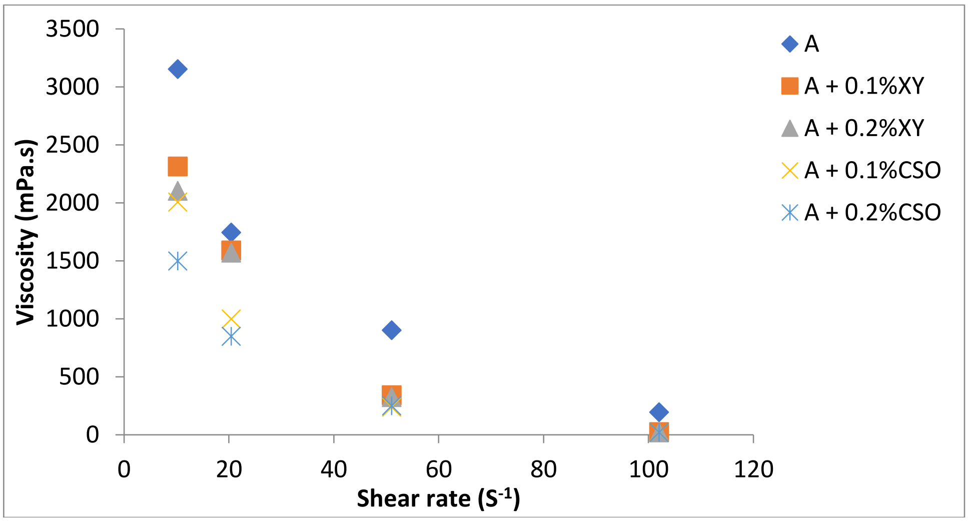

Figure 3. Viscosity against shear rate of crude oil sample A doped with xykene and CSO

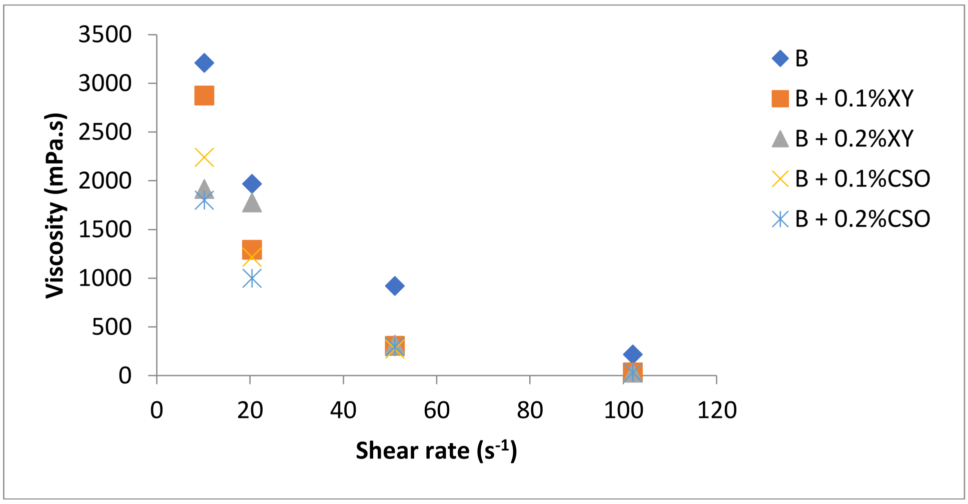

Figure 4. Viscosity against shear rate of crude oil sample B doped with xykene and CSO

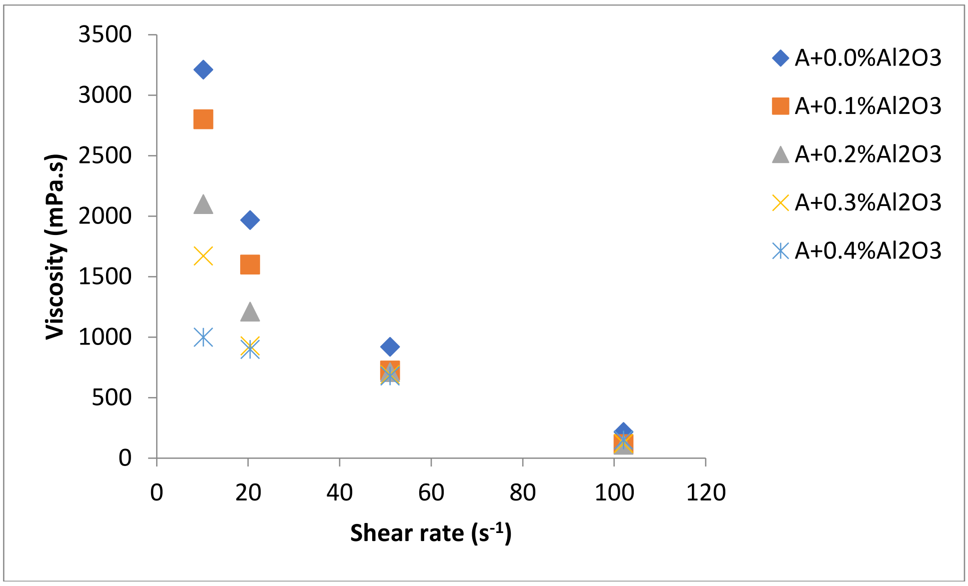

Figure 5 Viscosity against shear rate of crude oil sample A doped with Al_2O_3

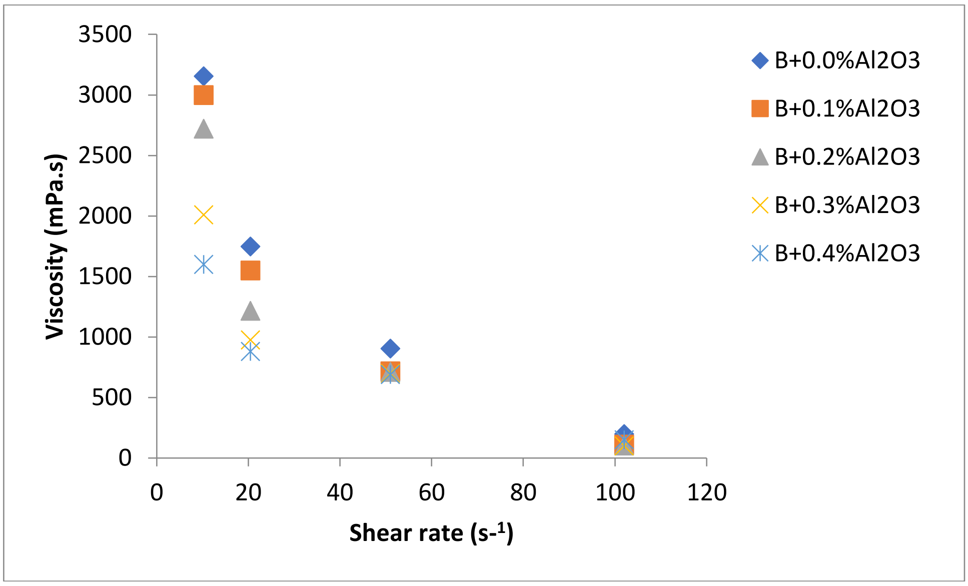

Figure 6. Viscosity against shear rate of crude oil sample B doped with Al_2O_3

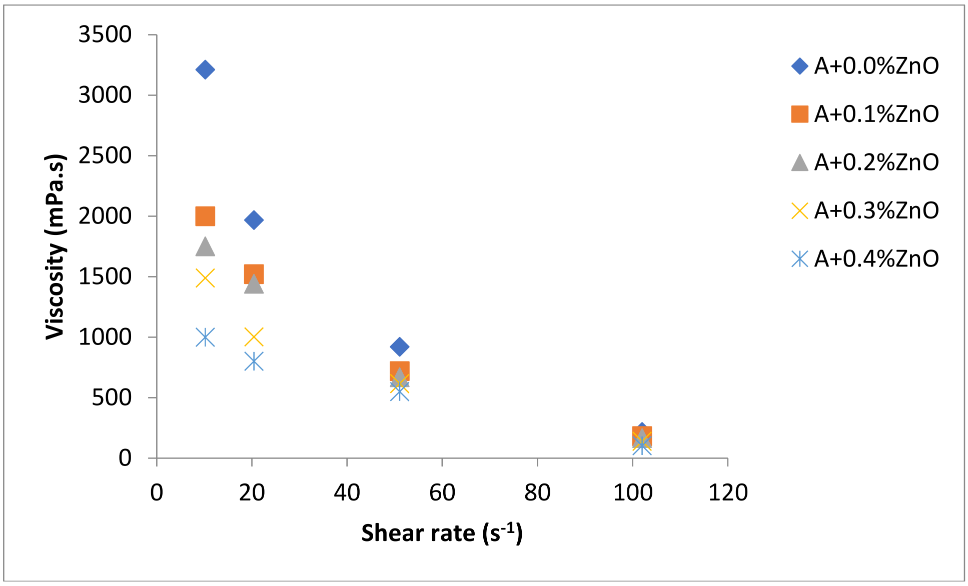

Figure 7. Viscosity against shear rate of crude oil sample A doped with ZnO

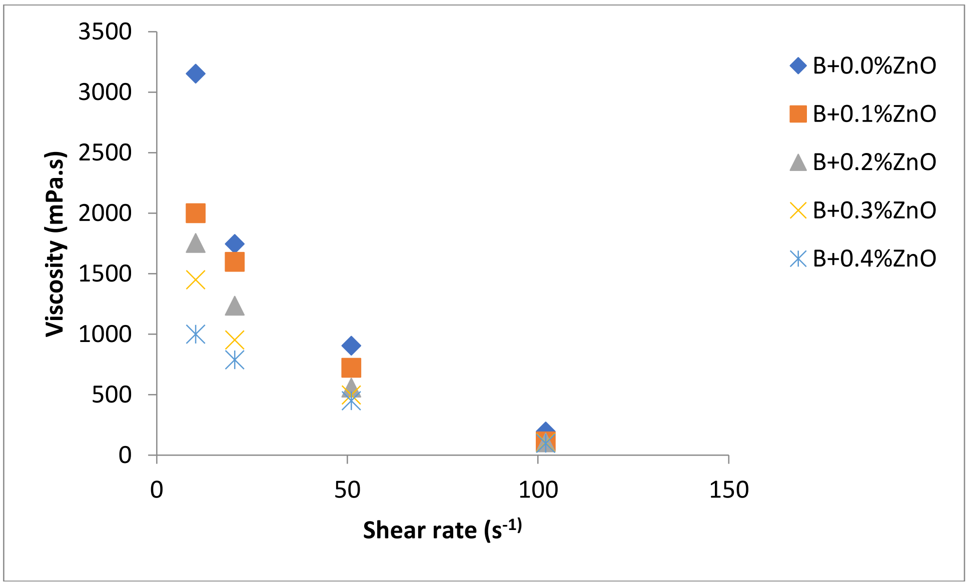

Figure 8 Viscosity against shear rate of crude oil sample B doped with ZnO

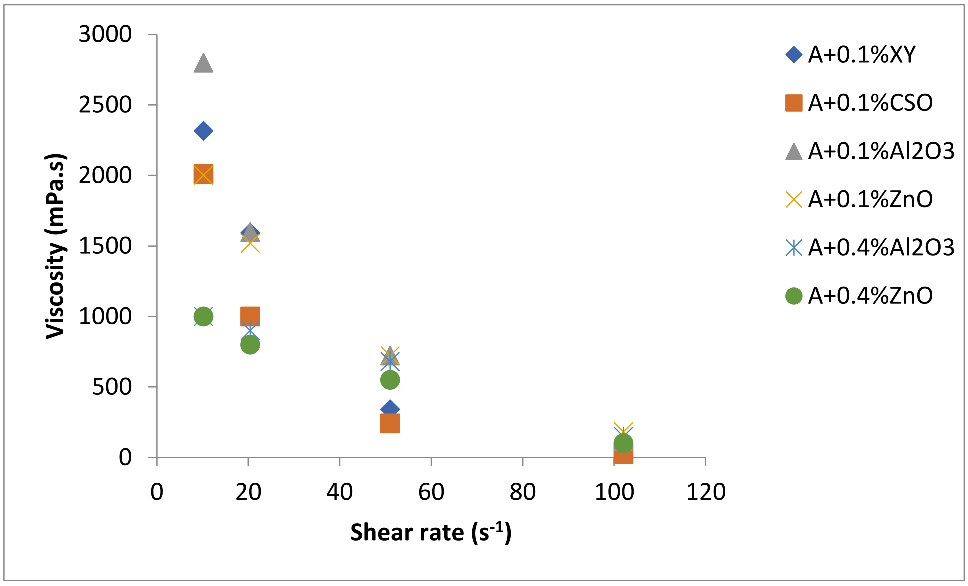

Figure 9 Viscosity against shear rate of crude oil sample A doped with Al_2O_3, ZnO, xylene and CSO

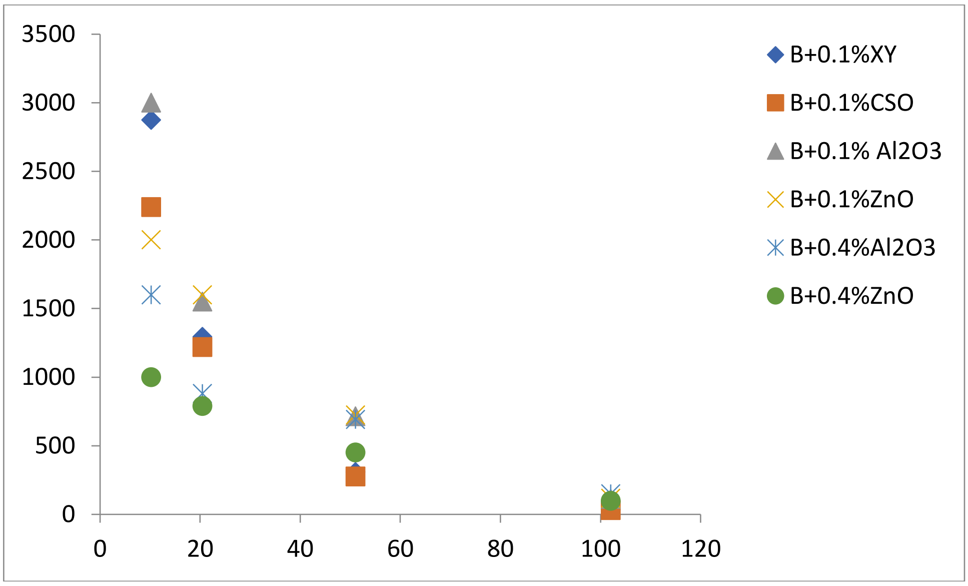

Figure 10 Viscosity against shear rate of crude oil sample B doped with Al_2O_3, ZnO, xylene and CSO

The pour points of sample A was steadily reduced by xylene and CSO as their conventration increased from 0.1% to 0.4% (Figure 11). This was in agreement with the findings of previous researchers (Akinyemi et al., 2016; Bello et al., 2005). The Al_2O_3 and ZnO nanoparticles also reduced the pour point of sample A as the concentration increased from 0.1% to 0.4%, though not as much as CSO and xylene did (Figure 11). It was however, observed that ZnO nanoparticles behaved better than the Al_2O_3 nanoparticles in reduction of the pour point of sample A. Thus, ZnO was able to interact with the molecules of the sample A to reduce the pour point of the sample. This is agreement with performance of the ZnO nanopartices on the viscosity of sample A in Figure 7. ZnO was able to reduce the pour point of sample A from 17ºC to 10ºC at 0.4% concentration of doping. Furthermore, it was observed that the chemical additives displayed similar trend of impacts on the pour point of sample B as was displayed for sample A (Figure 12).

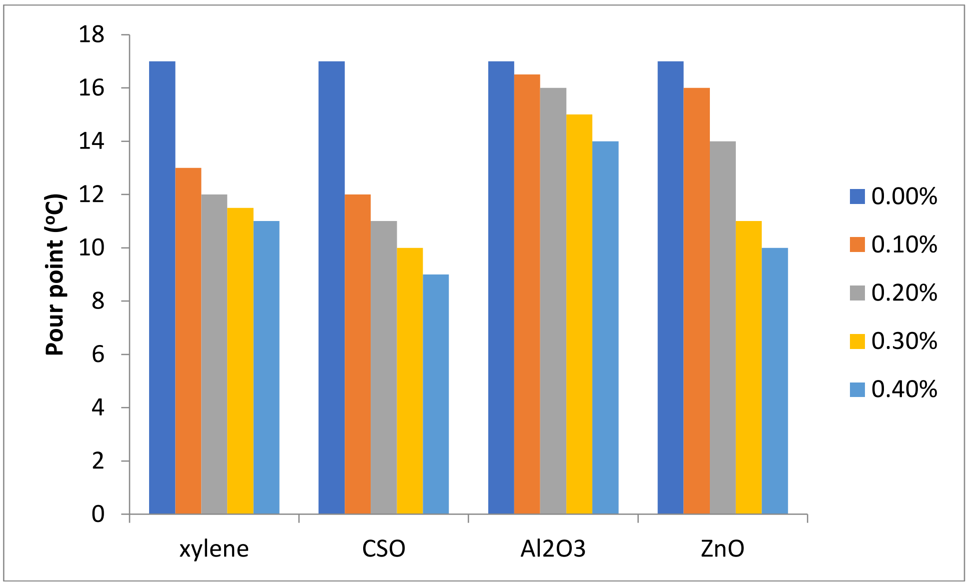

Figure 11 Pour points of sample A doped with additives

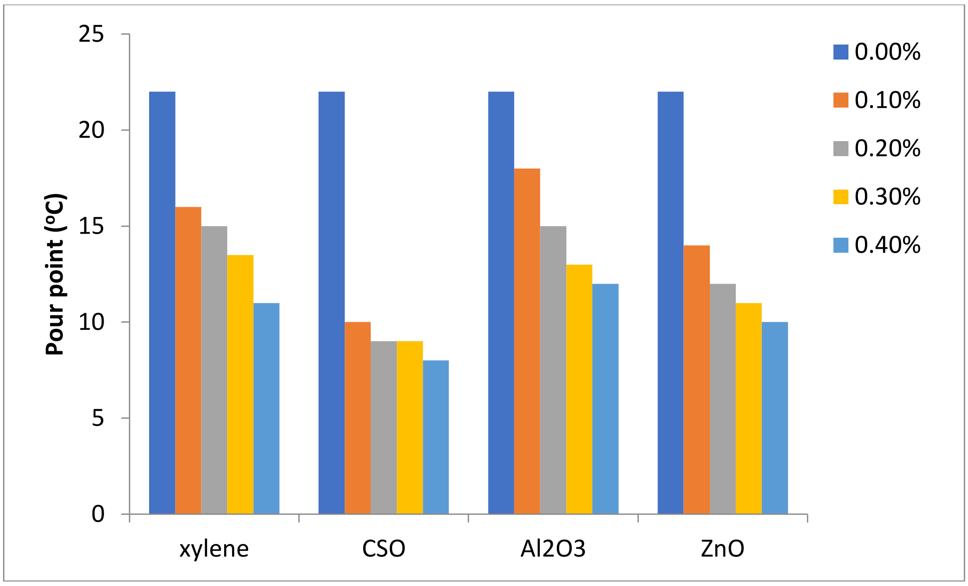

Figure 12 Pour points of sample B doped with additives

IV. Conclusion

The impacts of plant seed oil CSO, xylene, aluminium oxide (Al_2O_3) nanparticles, and zinc oxide (ZnO) nanoparticles on the rheological properties of Nigerian waxy crude oil obtained from Niger Delta area were investigated. ASTM standard methods were used to determine the API gravity, pour point, viscosity, hydrocarbon composition of the crude oil samples. The variations of the viscosities and pour points with concentrations of the four chemical additives from 0.1% to 0.4% were determined. It could be concluded that the Al_2O_3 and ZnO nanoparticles could depress the pour points of the two samples considered and reduce the viscosity appreciably as the CSO and xylene though in with higher concentration. It is recommended that ZnO should be considered for use as pour point depressant or as a blend with other suitable chemical for formulation of pour point depressant.

REFERENCES

[1]. Ahmed, T. (2007) Equations of State and PVT Analysis. Aplications for improved reservoir modeling. Gulf Publishing Company Houston, Texas.
[2]. Akinyemi O. P., Udonne J. D. and Oyedeko K.F.K. (2018). Study of effects of blend of plant seed oils on wax deposition tendencies of Nigerian waxy crude oil. Journal of Petroleum Science and Engineering, 161 (2018) 551–558
[3]. Akinyemi O. P., Udonne J. D., Efeovbokhan V. E., Ayoola A. A., (2016). A study
[4]. on the use of plant seed oils, triethanolamine and xylene as flow improvers of Nigerian waxy crude oil. Journal of Applied Research and Technology, 14(2016), 195-205

[5]. Bello, O.O., Fasesan, S.O., Akinyemi, P.O., Macaulay, S.R.A., Latinwo, G.K., 2005. Study of the influence of xylene-based chemical additive on crude oil flow properties and paraffin deposition inhibition. Eng. J. Univ. Qatar 18, 15–28.
[6]. Chala, G. T., Sulaiman, S. A., & Japper-Jaafar, A. (2018). Flow start-up and transportation of waxy crude oil in pipelines-A review. Journal of Non-Newtonian Fluid Mechanics, 251, 69–87.
[7]. Deshmukh, S. and Bharabhe, D.P. 2008. Synthesis of polymeric pour point
[8]. depressants for Nada crude oil Gujarat, India) and its impact on rheology, Fuel Processing Technology, 227-233
[9]. Ganeeva, Y. M., Yusupova, T. N., & Romanov, G. V. (2016). Waxes in asphaltenes of crude oils and wax deposits. Petroleum Science, 13(4), 737–745.
[10]. Lira-Galeana, C., & Hammami, A. (2000). Wax precipitation from petroleum fluids: A review. In F. Y. The & G. V. Chilingarian, (Eds.), Developments in petroleum science (Vol. 40, pp. 557–608). New York: Elsevier.
[11]. Mahto, V, Verma, D and Singh, H, 2010, Kinetic study of wax deposition in the
[12]. flow lines due to Indian crude oil, Proc. First International Conference on Drilling Technology, November 18-21, 2010, I.I.T., Madras, Chennai.
[13]. Soni H. P., Bharambe D. P. (2006). Synthesis and evaluation of polymeric additives as flow improvers for Indian crude oil. Iranian Polymer Journal, Vol. 15, No. 12, 943 – 954
[14]. Taiwo E. A., Fasesan S. O., Akinyemi O. P. (2009). Rheology of doped Nigerian Niger-Delta waxy crude oil. Petroleum Science and Technology, 27, 1381-1393, Taylor and Francis group