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Effect of Aluminum Oxide (AL203) Nanoparticle on the Viscosity of Niger Delta Waxy Crude at Varying Temperatures

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Abstract— Wax formation in crude oil transportation pipeline the fluid viscosity, resulting in an increased pressure required for fluid flow with a corresponding additional pump horsepower. In severe cases, wax deposition may lead to complete pipe blockage. It is therefore imperative to monitor and reduce the viscosity of waxy crude flowing in pipelines. Current solutions commonly used to prevent or mitigate wax deposition includes scrapers, pig, treatment with hot oil. This work examines the use of Aluminum oxide (Al_2O_3) nanoparticle for waxy crude viscosity reduction at varying temperatures. The waxy crude oil sample was contaminated with 1wt%, 2wt%, 3wt% and 4wt% Aluminum oxide nanofluid respectively and the viscosity was measured at 10°C, 15°C, 20°C, 25°C, 30°C and 35°C. It was observed that waxy crude viscosity reduced with increase in temperature. At low temperature of 10°C and 15°C, 4wt% was the optimal dosage of the Aluminum oxide nanoparticle as it reduced the viscosity of the crude sample from 72.5mPa•s to 55mPa•s. At high temperature of 30°C and 35°C, the effect of Aluminum oxide nanoparticle was minimal because the wax particles had already melted. Aluminum oxide nanofluid is highly recommended for wax prevention in low-temperature environment and can be applied in offshore fields to reduce the viscosity of waxy crude oil.

Index Terms—Aluminum oxide nanoparticle, Niger Delta waxy crude, Viscoisty reduction, Wax prevention

1 INTRODUCTION

CRUDE oil is a naturally occurring flammable liquid consisting of hydrocarbons and heteroatomic organic compounds of various molecular weights. According to the Organization of the Petroleum Exporting Countries (OPEC), Nigeria has the 8th largest proven oil reserve in the world [1]. TheNiger delta crude oil is produced from sandstone facies within the Agbada formation. The oil within the delta has an API gravity range of 16-500 API [2], with lighter oils having greenish-brown colour. Common oil production problems in the Niger delta include water conning, unconsolidated sands, high gas-oil ratios and wax decomposition.

Wax deposits are commonly paraffin and asphaltenes. Waxes from Niger Delta crude oils are paraffinic [3] [4], while waxes from California, Venezuela and Trinidad crudes are asphaltenic [5]. Wax exist in a dissolved state in the crude oil stream at reservoir conditions. Waxy crude oil is Non-Newtonian in nature, exhibiting properties of liquid and solids. As the oil temperature hits below its wax appearance temperature (WAT), the wax solid molecules crystalize out and subsequently transform into wax gel with high yield strength which surrounds the cross-sectional area of the production pipelines, increasing the viscosity of the crude oil and reducing flowability of the oil.The crystals formed of paraffin wax are known as macrocrystalline wax [6].

Paraffin wax deposition occurs when paraffin begins to crystallize forming a crystal nucleus, further precipitation of paraffin crystals causes the crystals to coagulate, forming larger crystals that deposit on the surface of the pipelines blocking the annulus of the pipeline and causing a reduction in production as oil is being lost to the formation of wax. Paraffin wax deposition can cause serious flow assurance problems on oil production, storage, transportation, handling and processing.

Paraffin wax deposition can be prevented using methods that prevent a reduction in the crude oil temperature such that the oil does not attain its WAT. This can be done by pipe insulation and heat treating the pipe [7]. The roughness of the internal pipe wall may promote wax deposition [8]. Hence ensuring a smooth internal pipe wallwill lower the rate of paraffin wax deposition. This can be achieved by using plastic (epoxy, phenolic, etc) coated pipes. These preventive methods are very expensive to implement, especially in offshore environment. It is therefore desirable to control wax deposition by use of Pigging [9], pipe heating [4], Scraping [10], use of Chemical solvents to reduce the oil viscosity [11] [12] and use of chemical dispersants such as surfactants

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[13] and more recently the use of nanoparticles [14], [15] [16]. In this study, the effect of Al_2O_3 nanoparticle on the viscosity of Niger Delta crude oil is evaluated.

2 METHODOLOGY

The Niger delta crude oil sample used in this analysis has a wax content of 36.58%, an API of 43.19 and a density of 50.5441b/ft3. The viscosity of the crude oil sample at varying temperature was measured usinga Znn-d12 viscometer. For each viscometer measurement, 300ml of the crude sample was used. The crude sample was conditioned to temperatures 10°C, 15°C, 20°C, 25°C using a chiller while a water bath was used to condition the crude sample to 30°C and 35°C. 100ppm of Al_2O_3 Nano fluid was prepared by dissolving 0.01g of Nano Aluminium Oxide (Al_2O_3) in of xylene (base fluid) by continuous stirring in a mixer at 1500rpm for 30mins. The effect of 1wt%, 2wt%, 3wt% and 4wt%(based on the 300ml sample requirement of the viscometer) of the Al_2O_3 nanofluid on the viscosity of the crude sample was evaluated at varying temperatures.

3 RESULTS

The viscosity of the waxy crude sample decreased with increase in temperature. At a temperature of 10°C, the viscosity was as high as 72.5mPa•s. While at a temperature of 15°C, the viscosity had reduced to 59mPa•s. Further increase in temperature effected a reduction in the crude oil viscosity. This is because the precipitated paraffin heating up and melting back to liquid. Notice that there was no change in viscosity at temperatures of 30°C and 35°C. This is because at 30°C, the entire paraffin wax particles contained in the crude sample has completely returned to the liquid state, and there are no paraffin crystals dispersed in the crude oil sample.

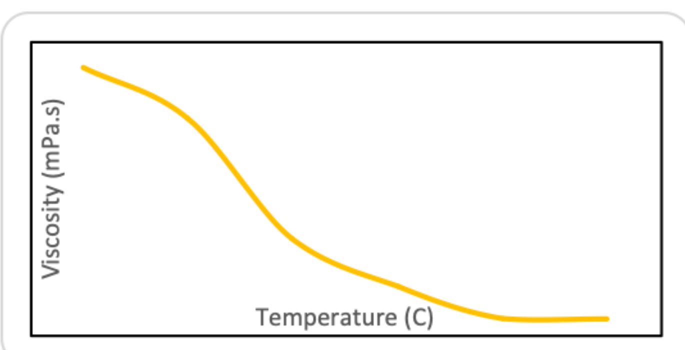

Figure 1: Viscosity against Temperature of blank crude oil sample

To study the effect of Al_2O_3 nanoparticles on the viscosity of the crude sample at varying temperatures, 1wt%, 2wt%, 3wt% and 4wt% respectively of the prepared Al_2O_3 nanofluid was mixed with the crude sample and the viscosity measured at 10°C, 15°C, 20°C, 25°C, 30°C and 35°C respectively.

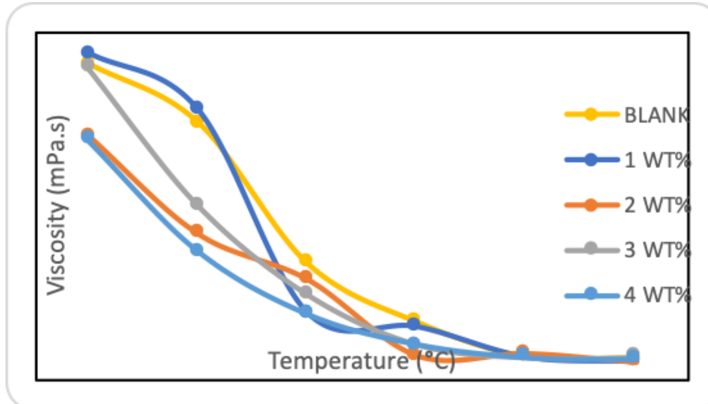

Figure 2: Plot of dynamic viscosity as a function of concentration against temperature

Notice that with increasing temperature, a reduction in viscosity was observed in all crude samples in this study (Figure 2). This is because the wax crystals melt to liquid due to the increase in temperature and rise in kinetic energy of the crude sample. Also, there was no significant difference between the viscosity of the blank crude sample and the crude samples containing different concentration of Al_2O_3 nanofluid at 30°C and 35°C. This is because the wax samples have completely gone into solution at these temperatures.

The viscosity of the blank crude increased to 75mPa•s with the addition of 1wt% Al_2O_3 nanofluid (Figure 3) at a temperature of 10°C. However, a further increase in Al_2O_3 nanofluid concentration to 2wt% caused a decrease in the viscosity to 56mPa•s. It later increased to 71.5mPa•s when 3wt% Al_2O_3 nanofluid was added to the crude and viscosity dropped to 55mPa•s when 4wt% Al_2O_3 nanofluid was added to the crude oil sample.

The addition Al_2O_3 nanofluid generally reduced the dynamic viscosity of the crude oil samples at the temperatures studied except for the addition of 1wt% Al_2O_3 nanofluid at 10°C and 15°C which caused an increase in crude oil viscosity. The reduction of viscosity caused by the addition of Al_2O_3 nanofluid at the different temperatures understudy did not follow a definite trend. From the bar chart (figure 3), the best concentration for each temperature considered is easily seen.

At 10°C, the 4wt% Al_2O_3 nanofluid was the best performing concentration of the Al_2O_3 nanofluid because it caused a reduction in viscosity from 72mPa•s to 55mPa•s. At 15°C, the 4wt% Al_2O_3 nanofluid was the best performing concentration of the Al_2O_3 nanofluid because it caused a reduction in viscosity from 59.5mPa•s of the blank crude to 29.5mPa•s. The best performing concentration was 1wt% at 20°C, effecting a decrease in crude oil viscosity from 26.5mPa•s to 15.2mPa•s. At 25°C, 2wt% nanofluid performed best, effecting a decrease in viscosity from 13mPa•sto 5.5mPa•s.

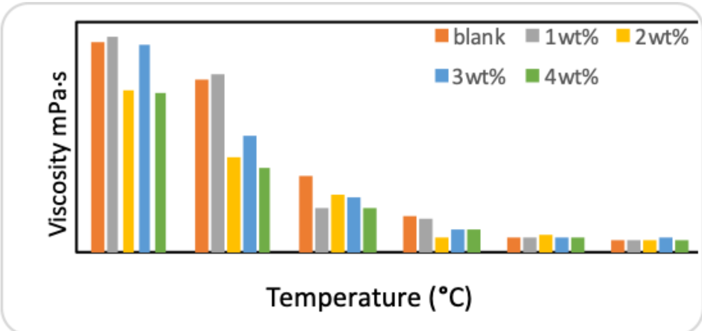

Figure 3: Viscosity variation of crude sample contaminated with Al_2O_3 at varying temperatures

At 30°C and 35°C, the crude oil viscosity has been sufficiently reduced by heat applied and the effect of the nanofluid is very minimal. At 30°C, the viscosity of the samples remained at 5 mPa•s in all nanofluid concentration under study except when 2wt% of nanofluid was added, a slight increase from 5 mPa•s to 6 mPa•s was observed. The best performing concentration at 35°C are 1wt% and 2wt%.

4 CONCLUSION

The viscosity of the Niger delta crude sample decreased with increase in temperature. Addition of nanoparticles caused a further decrease in the viscosity at lower temperatures (10°C to 25°C). The effect of the nanofluid was inconsequential at the higher temperature of 30°C and 35°C. This is because, at these temperatures, the wax molecules are already dissolved. Aluminum oxide nanofluid is efficient in reducing wax precipitation and improving the viscosity of the Niger delta crude sample under study at low temperatures. It is therefore recommended for offshore application.

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