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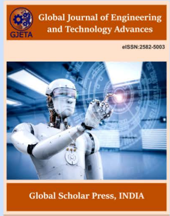

(RESEARCH ARTICLE)

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The effect of polyethylene butene (PEB) and xylene on the shear stress of Niger delta crude oil

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Abstract

Crude oil production and transportation is plagued by several flow assurance issues especially in offshore environment with prevailing low temperature. One of the flow assurance challenges is the deposition of paraffin wax which usually changes the crude oil flow from Newtonian fluid flow to non- Newtonian fluid flow with increased viscosity. This increased viscosity can impede flow causing the installation of high horsepower pumps for fluid flow. In severe cases, paraffin wax has plugged the pipes and caused production disruption. It is therefore imperative to manage paraffin disposition in crude samples containing paraffin compounds (C^{18+}). This research discusses the use of varying concentrations of Polyethylene Butene (PEB) in managing wax precipitation at various temperatures (10 °C to 35 °C) at a constant shear rate of 511(s^{-1}). The reduction in crude oil temperature increased the shear stress in all experiments conducted. It was discovered that the increasing concentration of PEB from 500ppm to 5000ppm had a sinusoidal effect on reducing the shear stress. 500ppm of PEB effected a 19% reduction in shear stress, while 5000ppm effected a 35% reduction in shear stress. It is important for the engineer to make the choice of inhibitor concentration based on the degree of shear stress reduction required to optimize inhibitor usage.

Keywords: Polyethylene Butene; Waxy Crude; Shear stress; Nigerian crude oil; Flow Assurance

1. Introduction

Pipelines as a means of transporting crude oil from the producing field to the treatment station or the refinery is relatively inexpensive, effective, and environmentally convenient. Pipelines have been widely used in the gathering process at the oilfield and for downstream fuel supply.

During offshore transportation, paraffin precipitation may occur due to temperature loss to the surroundings. The precipitation of waxes from petroleum mixtures at low temperatures is an important flow assurance problem in oil production as it can cause economic losses which may even lead to abandoning wells (Ferworn et.al 1997).

The wax present in petroleum crudes primarily consists of paraffin hydrocarbons known as paraffin wax and naphthenic hydrocarbons. These molecules can be either straight or branched hydrocarbon chains and can contain some cyclic and/or aromatic hydrocarbons (Huang et al, 2016). Hydrocarbon components of wax can exist in various phases either gas, liquid or solid depending on their temperature and pressure. When the wax freezes, it forms crystals. The crystals formed of paraffin wax are known as macrocrystalline wax (Figure1). Those formed from naphthenes are known as microcrystalline wax (Figure 2).

A collection of normal paraffins with 16 or more carbon atoms (C≥16) form crystalline solid substances at cloud point, are known as wax (Ragunathan et al, 2020). The severity of the wax deposition problems depends on type of oil and the

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molecular composition of the wax molecules. The waxes in crude oils are often more difficult to control when compared to condensate, because the alkane chains are often longer in the crude oil than in the condensate, which consists of lighter hence shorter hydrocarbons.

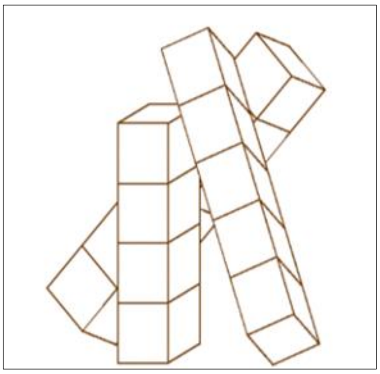

Figure 1 Macrocrystalline (Mansoori, 2009)

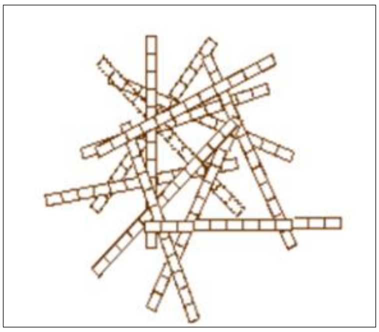

Figure 2 Microcrystalline (Mansoori, 2009)

Wax causes artificial blockage in flow path, leading to a reduction or interruption in production. In extreme cases, this can cause a pipeline or production facilities to be abandoned (Tao, et al, 2008). Downhole, wax deposition also leads to formation damage near the wellbore, reduction in permeability, changes in the reservoir fluid composition and fluid rheology due to phase separation as w ax solids precipitates (Sandyga, et al, 2020). One of the important issues to be noted is that the wax deposit is not just solid wax but a gel that consists of solid wax crystals and trapped liquid. This blockage chokes the production lines thereby reducing the oil production to uneconomical levels. Apart from the reduced flow, shutdowns are necessary to apply various treatment techniques to deal with the problem (Theyab, 2020), causing loss in revenue. Additionally, blockage caused by asphaltene deposition along the walls of the pipeline, reduces the accessible cross-sectional area for oil flow, which will induce a rise in the pressure drop and a reduction in the flow rate (Filippo, 2011).

Wax appearance on the pipe wall both surface and subsurface is inevitable because pipeline crude runs thousands of kilometers offshore characterized by low temperature which in turn affects the rheological properties of the crude (viscosity, density, gel strength etc.). An increase in fluid viscosity corresponds to an increase in density, thereby reducing flow rate which resulting to pressure abnormalities (pressure drop). This blockage chokes the production lines thereby reducing the oil production to uneconomical levels. Industrial experts have made considerable effort to remediate wax deposition downhole and on surface by employing several methods like mechanical pigging (Aslanov et al, 2019) which has proven to be expensive due to pigging frequency (Towler et al, 2011). Other techniques that have been used to manage gas hydrates include: thermal (Nysveen et al, 2005)., bacterial (Asma, 2007), chemical (Odutola and Idemil, 2020, Odutola and Allaputa 2020,) and electromagnetic treatments (Tung et al, 2001).

In practice, the use of a single method is not effective and therefore a combination of these methods is applied (Becker, 2000). Among the different treatments, the use of chemical inhibitors has increased in the oil industry although chemical inhibitors may give different results for wells draining from the same reservoir causing the application of different chemical to be restricted to specific wells. The main variables used in evaluating wax precipitation are Wax Appearance Temperature (WAT), the amount of precipitated solid as a function of the Wax Precipitation Curve, (WPC), pour point, and gel point. The knowledge of these variables is crucial to estimate wax precipitation potential and to determine the best strategy to control and mitigate the problem.

Although there is limited literature on the effect of nanoparticles on Niger Delta waxy crude shear stress, Odutola and Idemili (2020) reported the effect of the blend of PEB and Nano Al_2O_3 on waxy crude viscosity; Odutola and Allaputa (2020) studied the effect Nano Al_2O_3 on the viscosity of Niger Delta crude oil and Balogun et al (2021) studied the effect of PEB and Nano ZnO on Niger Delta waxy crude viscosity.

This work seeks to economically mitigate wax deposition problem by evaluating the effect of polyethylene butene and xylene on the shear stress of the crude at varying temperature. Fluid shear stress refers to the unit area amount of force that acts on a given fluid parallel to a small element of the surface. For a fluid to resist shear stress, it must be in motion. In Newtonian fluids, the shear stress is proportional to the shear strain rate. However, this is not true for non-Newtonian fluids like waxy crude.

This study evaluates the effect of the PEB on the shear stress of a Niger Delta waxy crude sample at a constant shear rate with varying fluid temperature.

2. Material and methods

The materials used in this study include Niger Delta crude oil sample, Xylene, Polymer – polyethylene butane (PEB) and ice block as a coolant.

Equipment used in this study include a Znd d12 speed rotary viscometer for measuring the viscosity of the fluid, a hydrometer for measuring crude sample specific gravity, a mixer for blending the inhibitor with the crude sample; measuring cylinders and syringe for measurement; thermometer, water bath, electronic weighing balance and stopwatch.

A practical approach was adopted, it involved determining the rheological properties of a blank crude sample and comparing it with the effect of polymer-polyethylene butane (PEB) on the crude sample.

2.1. Procedure

The chromatogram of the crude was carried out to analyse the various compounds in the crude sample. Gas chromatogram is used to separate different components of a mixture to know various petroleum fluid mixtures for analysis. The crude specific gravity was measured using a hydrometer. The density and the API gravity were estimated using the equations:

$$\gamma_o = \rho_o / \rho_w \qquad \text{.................(1)}$$

Where, γ_o = specific gravity of oil
ρ_o = density of oil
ρ_w = density of water = 1Ib/ft^3

The API gravity is obtained using this equation:

$$API = \frac{141.5}{\gamma} - 131.5 \qquad \text{..............(2)}$$

Four different concentrations of Poly (ethylene-butene) (PEB); 500ppm, 1000ppm, 2000ppm and 5000ppm solution were prepared by mixing 0.02ml, 0.04ml, 0.08ml and 0.2ml of the polymer respectively in 40ml (for each concentration) of xylene which was used as the solvent, at continuous stirring in a mixer at 1500rpm for 30mins. A fixed volume of 3mls for each inhibitor concentration was used in each experiment conducted with xylene and PEB.

3. Results and discussion

The physical properties of the Niger Delta crude sample are as shown in Table 1. The API gravity of 43 indicates the crude is a light crude however, the crude sample chromatogram (Figure 3) indicated a high proportion of waxy compounds with carbon chain 18 and above. This implies that at the wax appearance temperature (WAT), wax crystals will precipitate out of the crude sample and when not managed, will cause crude gelation, and increase in the crude viscosity.

Table 1 Physical Properties of the Blank Crude

Temperature (ºC)	**28**
Density (1b/ft3)	50.544
Specific Gravity	0.81
API Gravity	43.191

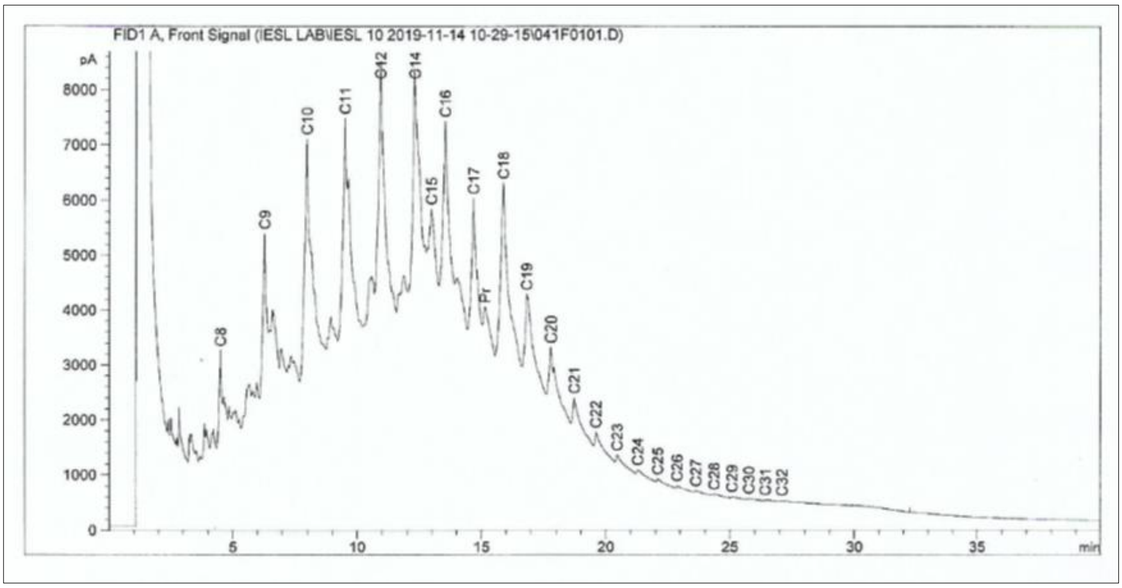

Figure 3 Chromatogram of the Niger Delta crude sample

At a constant share rate of 511(s^{-1}), the shear stress was measured at varying temperatures of 10 to 35 °C for blank crude sample (Figure 4). Notice that at low temperature of 10 °C, the shear stress was the highest at 37mPa. At the highest temperature of 35 °C, the shear stress was the lowest with a value of 3mPa. Notice that the shear stress of the blank crude for temperatures 35 °C and 30 °C was the same value of 3mPa, the crude sample is still Newtonian at these temperatures. This is because these temperatures are above the wax appearance temperature, no wax crystals had formed in the crude sample and there was no change in viscosity. As the crude temperature decreased to 25 °C, the shear stress increased to 6.6 mPa, implying that the crude sample had reduced below the WAT and wax crystals have started precipitating, causing resistance to easy fluid flow, and increasing the shear stress. The shear stress progressively increased with decreasing temperature of after the WAT was attained between 25 °C and 30 °C. This increase in shear stress was due to causing the precipitation and growth of wax crystals.

The amount of wax precipitated increased with the decrease in temperature as indicated by the rising shear stress from crude oil gelation.

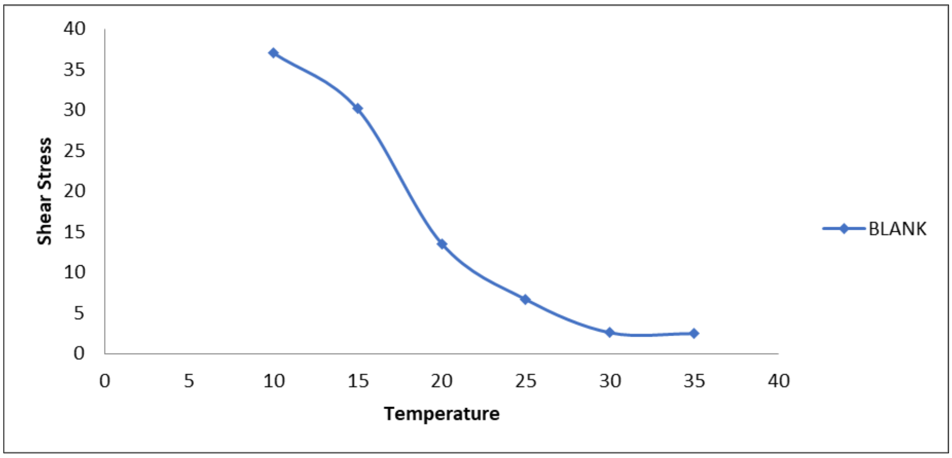

Figure 4 Graph of Shear Stress of Blank Crude Against Temperature

To evaluate the effect adding PEB to the crude oil shear stress at varying temperatures, the plot of the temperature against shear stress for experiments conducted with 500ppm, 1000ppm, 2000ppm and 5000ppm of PEB/xylene mixture at a shear rate of 511 s^{-1} is shown (Figure 5). Notice that in all experiments conducted with PEB, the shear stress progressively increased as the crude temperature decreased. This is seen significantly as the crude oil temperature is cooled below 30 °C, implying that wax crystal precipitation commenced as crude oil temperature is cooled below 30 °C. The shear stress was the highest with a value of 37.0 mPa at 10 °C, the lowest temperature considered in this study. The rise in shear stress is an indication of rapid precipitation of wax crystals in the fluid which causes resistance to flow and hence, increases the fluid shear stress.

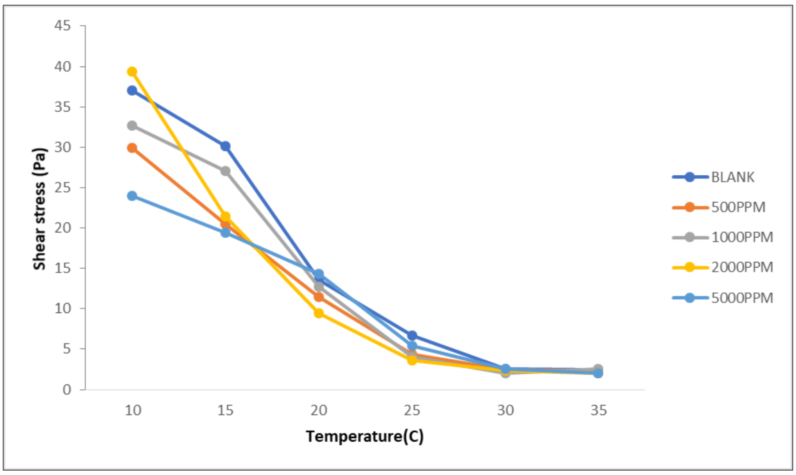

Figure 5 Shear stress versus temperature for crude oil with varying concentration of PEB

The PEB/xylene inhibitor reduced the shear stress of the crude oil and this was very evident at cold temperature of 15 °C and 10 °C. At the temperature of 10°C, the shear stress reduced from 37mPa to 30 mPa with the addition of 500ppm of PEB/xylene mixture. However, further increasing the concentration of the PEB/xylene inhibitor to 1000ppm was less effective as the reduction in shear rate was less (from 37 mPa to 32 mPa). This implies that the effective inhibitor dosage had been exceeded. Increasing the concentration of PEB to 2000ppm further increased the shear stress to 39 mPa. As the inhibitor concentration is increased to 5000ppm, the shear stress is further reduced to 24 mPa.

The percentage shear stress reduction is computed at crude oil temperature of 10 °C using the following expression:

$$\text{Percentage reduction (\%)} = \frac{\tau_{blank} - \tau_{dosed}}{\tau_{blank}} \times 100 \qquad \text{..........(3)}$$

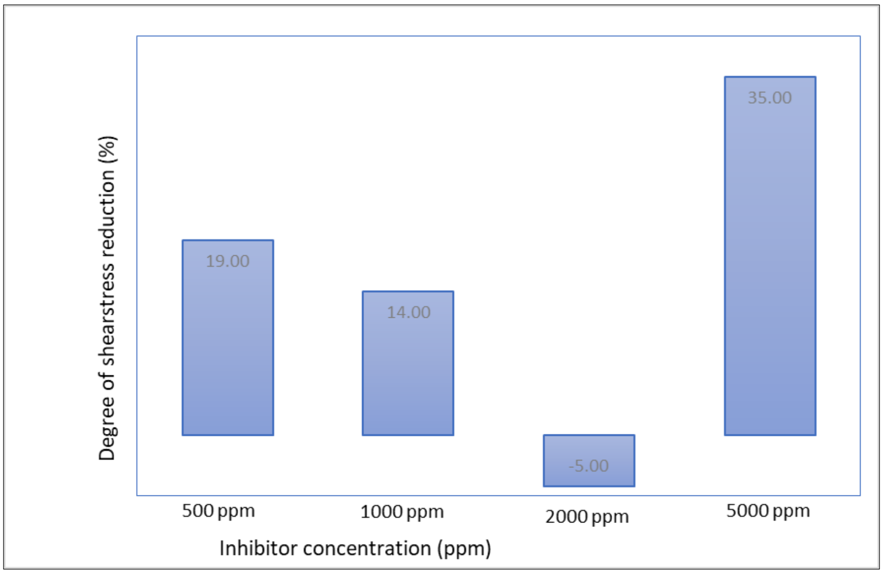

Figure 6 Degree of shear stress reduction

The inhibitor effect on shear stress reduction is depicted graphically in Figure 6. Notice that 5000ppm of PEB/xylene mixture contaminant gave the most significant reduction in shear stress for the concentrations considered in this study. To make the right inhibitor choice, it is imperative to select the most effective inhibitor concentration with the least volume which is 500ppm. Although it does not inhibit as much as 5000ppm, 10times less inhibitor is used in achieving 19% shear rate reduction. This is an economic decision. The engineer should be able to decide if proceeding with 10 times more volume of inhibitor to achieve an additional 16% reduction in shear stress will be profitable to the company. However, if at 500ppm and 19% reduction in shear rate, the fluid can flow effectively, it is best to select the less volume inhibitor.

4. Conclusion

Based on analysis on the effect of PEB polymer on the shear stress of Niger Delta crude investigated, it was observed that as temperature increased, there was a reduction in the shear stress of the crude thereby increasing the flow ability of crude. At lower temperatures it was observed that the blank crude had a higher shear stress and will experience flow resistance due to wax appearance and increased shear stress. The use of PEB was effective at reducing the shear stress. The best inhibitor concentration in this study based on its performance and the economic implication was 500ppm PEB.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

There is no conflict of interest.

References

[1] Asma E. (2007): “Microbial treatment of waxy crude oils for mitigation of wax precipitation,Journal of Petroleum Science and Engineering, Volume 55, Issues 1–2, 2007,Pages 111-121, https://doi.org/10.1016/j.petrol.2006.04.015.

[2] Aslanov, H., Novruzov, A., and Harun A. (2019):"Managing Wax-Deposition Risks in Oil Subsea Pipelines by Integrating Wax Modeling and Pigging Performance." SPE Prod & Oper 34 (2019): 625–634. doi: https://doi.org/10.2118/194506-PA

[3] Balogun A., Odutola T. O. and Balogun Y. (2021): Preventing Wax Deposition In Crude Oil Using Polyethylene Butene And Nano Zinc Oxide, Paper SPE-204317-MS presented at the SPE International Conference on Oilfield Chemistry held in The Woodlands, Texas, USA, 6 – 7 December, 2021. https://doi.org/10.2118/204317-MS

[4] Becker, J.R. (2000): "Oilfield Paraffin Treatments: Hot Oil and Hot Water Compared to Crystal Modifiers." Paper presented at the SPE Annual Technical Conference and Exhibition, Dallas, Texas, October 2000. doi: https://doi.org/10.2118/63123-MS

[5] Ferworn K. A., Hammami A., and Herb E. (1997): "Control of Wax Deposition: An Experimental Investigation of Crystal Morphology and an Evaluation of Various Chemical Solvents." Paper presented at the International Symposium on Oilfield Chemistry, Houston, Texas, February 1997. doi: https://doi.org/10.2118/37240-MS

[6] Filippo L.(2015): "Unconventional methods offer wax remediation options," Offshore Magazine, August 19, 2015. Available online at: https://www.offshore-mag.com/pipelines/article/16758623/unconventional-methods-offer-wax-remediation-options. Accessed on the 24th of June 2022.

[7] Huang Q., Wang W. , Li W., Ren Y., and Fangda Z. (2016): "A Pigging Model for Wax Removal in Pipes." Paper presented at the SPE Annual Technical Conference and Exhibition, Dubai, UAE, September 2016. doi: https://doi.org/10.2118/181560-MS

[8] Mansoori G.A. (2009): Phase Behavior in Petroleum Fluids (A Detailed Descriptive and Illustrative Account) Departments of BioEngineering, Chemical Engineering & Physics, University of Illinois at Chicago, Chicago, IL 60607-7052 USA

[9] Nysveen A., Kulbotten H., Lervik A., Bomes H., Hoyer-Hansen M. (2005): "Direct electrical heating of subsea pipelines - technology development and operating experience," Record of Conference Papers Industry Applications Society 52nd Annual Petroleum and Chemical Industry Conference, 2005, pp. 177-187, doi: 10.1109/PCICON.2005.1524553.

[10] Odutola T.O. and Allaputa V. (2020): “Effect of Aluminium Oxide (AL203) Nanoparticle on the Viscosity of Niger Delta Waxy Crude at Varying Temperatures”, International Journal of Scientific & Engineering Research Volume 11, Issue 1,pp 791-794, January-2020 ISSN 2229-5518

[11] Odutola T.O. and Idemili C.A. (2020): “Effect of poly (ethylene butene) and nano aluminium oxide blend on the viscosity of Nigerian crude oil,” Journal of Petroleum Exploration and Production Technology, Vol. 10, issue 4, April 2020

[12] Towler B. F., Jaripatke O. & Mokhatab S. (2011) Experimental Investigations of the Mitigation of Paraffin Wax Deposition in Crude Oil Using Chemical Additives, Petroleum Science and Technology, 29:5, 468-483, DOI: 10.1080/10916460903394029

[13] Ragunathan T, Husin H, Wood CD. (2020): “Wax Formation Mechanisms, Wax Chemical Inhibitors and Factors Affecting Chemical Inhibition”. Applied Sciences. 2020; 10(2):479. https://doi.org/10.3390/app10020479

[14] Sandyga, M.S., Struchkov, I.A. & Rogachev, M.K. Formation damage induced by wax deposition: laboratory investigations and modeling. J Petrol Explor Prod Technol 10, 2541–2558 (2020). https://doi.org/10.1007/s13202-020-00924-2

[15] Tao Z., Jack A. W., Liang J. (2008): "Evaluation of Wax Deposition and Its Control During Production of Alaska North Slope Oils," Prepared for United States Department of Energy National Energy Technology Laboratory by the Petroleum Development Laboratory Institute of Northern Engineering University of Alaska Fairbanks

[16] Theyab MA (2020): A Review of Wax Mitigation Methods through Hydrocarbon Production, Journal of Petroleum & Environmental Biotechnology. Vol. 11 Iss. 5 No: 412

[17] Tung, N. P,, Van Vuong N., Long B. Q. K., Vinh N. Q., Hung P. V., Hue, V. T., and Le D. H. (2001): "Studying the Mechanism of Magnetic Field Influence on Paraffin Crude Oil Viscosity and Wax Deposition Reductions." Paper presented at the SPE Asia Pacific Oil and Gas Conference and Exhibition, Jakarta, Indonesia, April 2001. doi: https://doi.org/10.2118/68749-MS