

Evaluation of Local Pour Point Depressant on Waxy Crude Oil

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Abstract: Pour point of crude oil has been a huge concern in flow assurance at some stage in crude oil production and transportation. Pour point depressants are used as chemical additives when transporting crude oils at temperatures below their pour point to prevent the fluid not to flow. Various chemical additives which are synthetic products are quite expensive for usage. This study utilizes oil extracted from plant waste material such orange peel (OP) and soya bean husk (SBH) as pour point depressants for Nigerian waxy crude oil. Effects of plant extracts on pour point of the two crude oil samples A and B were investigated using pour point apparatus. The waxy crude oil sample without pour point depressant, waxy crude oil sample doped with soya bean husk oil (SBHO), waxy crude oils sample doped with orange peel oil (OPO) and waxy crude oil sample doped with toluene gave pour point values of 86°F, 75.5°F, 64.48°F and 75.5°F then and 80.6°F, 75.2°F, 59°F and 80.6°F at 2800 ppm for waxy crude oil samples A and B respectively. The results obtained revealed that the oils extracted from these agricultural waste product could depress the pour points of the crude oil appreciably while orange peel oil (OPO) exhibited highest depression ability, however OPO which performed better than soya bean husk oil (SBHO) and Toluene and OPO could be a good substitute for pour point depressants for waxy crude oil.

Keywords: Pour Point Depressants, Waxy Crude Oil, Orange Peel Oil, Soya Bean Husk Oil

1. Introduction

Hydrocarbon production in deeper offshore environment come across cruel conditions that initiate adverse flow assurance concern in; (i) System deliverability: pressure drop versus production, pipeline size, and boosting. (ii) Thermal behaviour: temperature distribution, temperature changes due to start-up and shutdown, insulation selection and heating condition. (iii) Production chemistry: hydrates, waxes, asphaltenes, scaling, sand, corrosion and rheology. (iv) Operability characteristics: start up, shutdown, transient behaviour (e.g. slugging) and (v) System performance: mechanical integrity, equipment reliability [5].

A number of factors that lead to the majority of these issues could be attributed to (a) the change in hydrocarbon composition, (b) the difference in flow rates (due to the drop in pressure), (c) the reduction in hydrocarbon temperature (due to the heat transfer from the fluid to the immediate pipeline environment), (d) the raise in water production with oil (as free-water) and (e) the solid production [4]. Usually,

the average temperature at the seabed is usually about 4 – 16°C [10, 6] and the raise in pressure drops from the reservoir to surface facilities tremendously large [12, 13].

Therefore, in the flow assurance structure, engineers and the operators make every effort to build up efficient plans that are dependable and safe in production of hydrocarbon blend with least operating costs from the reservoir to processing facilities and at the point of sale [7] This area is thus vital for secure operation and economic feasibility of any oil and gas field. Therefore, applying suitable flow assurance strategies is indispensable in any oil field either to stay away from likely fluid problems completely or to be able to mediate on a continuous basis.

This trend is of particular apprehension in the production of crude oil from deep water field where the produced fluids may cool to nearly the temperature of the surrounding water, 4°C or even less [9]. Paraffin deposition in trunk lines and transmission lines exposed to cooler climatic conditions

remains an expensive aspect of getting oil to the market. For instance in Nigeria, pipelines (e.g. Zombie, Ashland) have been known to wax up beyond recovery [1]. Also, production tubing has been known to wax up (e.g. Ebocha, Agip) necessitating frequent wax cutting, which is expensive [2]. In 2007, 1500bpd was deferred due to wells closed in as a result of wax problems in Niger Delta crude oil field of Nigeria [15]. In a particular case, the wax deposition was so severe and frequent that an off-shore platform in the North Sea (Lasmo field in UK) had to be abandoned at a cost of about \$100,000,000. In the worst cases, production must be stopped in order to replace the plugged portion of the pipeline. The cost of this replacement and downtime is estimated approximately at \$30,000,000 per incident [8].

Akinyemi O. P. et al [3] carried out an Experimental Study by Utilizing Plant Seed Oil as Pour Point Depressant for Nigerian Waxy Crude Oil. They investigated the impact of plant seed oils and triethanolamine on the pour points of two waxy crude oil samples.

They found out that the plant seed oils depressed the pour points of the samples more than TEA at low doping concentrations and also reduced the viscosities of the samples. CSO and JSO performed better than the RSO could be used as pour point depressant in waxy crude oil. They added that an appropriate addition of the CSO to a waxy crude oil could result in as much as 11°C degree pour point depression of the waxy crude oil. They summarised that CSO and JSO which performed better than the TEA could be a good substitute for the chemical depressants.

Olusegun. P. A et al [11] studied the use of plant seed oils, triethanolamine and xylene as flow improvers of Nigerian waxy crude oil. Their results revealed that oil from the three seeds could be used as flow improvers and pour depressants for Nigerian waxy crude oil. They concluded that natural seed oil obtained from agricultural sources such as rubber seed, Jatropha seed and castor seed could be used as flow improver and pour point depressant for Nigerian waxy crude oil. They found out that Jatropha and castor seed oil could depress the pour point more than the previously investigated

triethanolamine. The active component of the seed oil which was involved in the interaction with the higher hydrocarbons in the crude oil is oleic acid, its derivative (rici-noleic acid) and oleate esters. These interactions brought about pour point depression and wax deposition inhibition, among others. Though crude oil from different sources tends to have different unique properties, the seed oil were able to display positive impacts on the flow ability of all the various crude oil samples tested having different hydrocarbon composition. Thus, their application as flow improver will cover a wide range of crude oil fields.

However this work is aimed at evaluating local pour point depressants such as orange peel oil (OPO) and soya bean husk oil (SBHO) in waxy crude oil from Niger Delta. The objectives of this study are; to develop pour point depressants using locally sourced non-edible orange peel and soya bean husk. Apply and investigate the solvent (oil) on waxy crude oil samples to determine pour point of the waxy crude oil and make comparison with an available patent chemical.

The inability of crude oil to flow is an impediment to crude oil production and flow line transportation in the Petroleum industry, whose occurrence if not correctly controlled could lead to high operational cost, downtime or system abandonment. In addition, the use of foreign pour point depressants still throbbing and leaves operational costs on the high side and as well not environmentally friendly. Hence the option for locally sourced green pour point depressants which is cheap and environmentally friendly in order to help foster sustainable development in Niger Delta.

2. Materials and Method

2.1. Materials

Materials used for the experimental research work was summarised in tables 1-3 below.

Table 1. Crude oil samples used for the study.

Material	Sample	Remark
Crude Oil	A	Obtained From Field In Niger Delta
Crude Oil	B	Obtained From Field In Niger Delta

Table 2. Materials used as Wax Inhibitors.

Material	Code	Source	Remark
Soya bean husk oil	SBHO	Soya bean husk	yellowish solvent
Orange peel oil	OPO	Orange peel	brownish solvent
Toluene	T	Vendor	colourless solvent

Table 3. IUPAC Name, Molecular Formula And Molecular Weight Of Materials Used.

Inhibitor	IUPA Name	Molecular Formula	Molecular Weight(g/mol)
Orange peel oil	(2-methyl(phenyl) diazenyl)naphthalen-2-ol	C ₁₇ NH ₁₄ N ₂ O	262.30
Soya bean husk oil	2-aminhoacetic acid	C ₂ H ₅ NO ₂	75.07
Toluene	Methylbenzene	C ₇ H ₈	92.14

Table 4. Components of Soxhlet extractor and Equipment used for oil extraction.

S/N	Equipment	Remark
1	Aspirator	contains water that goes into the inlet pipe
2	Condenser	cooling and condensation of the solvent
3	Extraction Chamber	hold samples for extraction
4	Round Bottom Flask	contains solvent and anti bumping
5	Inlet Pipe	takes water from aspirator to condenser
6	Outlet Pipe	takes water from condenser to containment can
7	Retort Stand	holds the soxhlet set-up
8	Measuring Cylinder	measuring the solvent (N-Hexane)
9	Filter Paper	holds grinded samples in the extraction chambers
10	Beaker	holds extracted oil
11	N-Hexane	solvent used for extraction
12	Anti- Bumping	make the N-Hexane to boil faster
13	Funnel	For transferring the N-Hexane into the soxhlet extractor

Table 5. Components Of Rotary Evaporator.

S/N	Component	Remark
1	Evaporation Flask	It is used for evaporation of samples
2	Rotary Motor	It is used to drive the evaporation flask at constant speed to obtain large evaporation area and evaporation efficiency
3	Heating Bath	It used for heating of samples in the evaporation flask and regulate temperature
4	Vacuum System	It is used to reduce pressure in the rotary evaporation system to achieve low boiling point of the sample at reduced pressure
5	Condensate Pipe	It is Used to condense the evaporated system
6	Evaporation Pipe	It is used to protect the sample during rotation and enables the vacuum system to suck out samples
7	Receiving Flask	It is used to recycle the sample after condensation

Table 6. Apparatus for experiment and their uncertainties.

s/n	Equipment	Remark	Uncertainty
1	Pour Point Apparatus	for pour point temperature of the waxy crude oil	
2	Thermometer	For measuring temperature	$\pm 0.5^{\circ}\text{C}$
3	Soxhlet Extractor	For extraction of liquid from sample	$\pm 0.1\text{ml}$
4	Rotary Evaporator	For efficient and gentle removal of solvent from sample by evaporation	$\pm 1\%$
5	Test Tube	For holding the crude oil samples in the pour point apparatus	
6	Volumetric Flask	For holding extracted oil and waxy crude oil samples	$\pm 0.05\text{ml}$
7	Pipette	For measuring the concentration of the inhibitor to be added to the waxy crude oil sample	$\pm 0.006\text{ml}$

2.2. Method

2.2.1. Extraction of Orange Peel Oil

500 kg of Orange peel were sourced from Port harcourt, Rivers State and was exposed to sunlight for drying. The drying process took 7 days to properly dry the samples. After drying, the samples were grinded using a grinding machine. 50g of the grinded orange peel was wrapped in a filter paper and put into the extraction chamber of the soxhlet, for effective extraction of the oil, the n-hexane (400ml) was administered through the top of the condenser with the aid of a funnel, the solvent passed through the condenser to the extraction chamber and finally settles at the round bottom flask mixing up with the anti-bumping. After inspecting the setup, the heating mantle (water bath) was put on, and setting the mantle to the boiling point of the n-hexane. As the n-hexane begins to boil, it evaporates from the round bottom flask through the extraction chamber which contains the sample and finally the condenser containing the water that cools the system traps the n-hexane and condenses it and it drops as liquid back into the extraction chamber and as the liquid n-hexane increases in volume in the extraction chambers it reaches the siphon point and then siphon back into the round bottom flask, this

process continues until the n-hexane in the extraction chamber becomes colourless, which indicates that the oil in the sample has been extracted and the separated oil is put into the rotary evaporator to gently and efficiently remove the solvent from the sample by evaporation at reduced pressure. This process is repeated until the required volume of the essential oil was obtained from the extraction process.

2.2.2. Extraction of Soya Bean Husk Oil

500 kg of soya bean husk were sourced from Port Harcourt, Rivers State and was exposed to sunlight for drying. The drying process took 1 day to properly dry the samples. After drying, the samples were grinded using a grinding machine. 50g of the grinded soya bean husk was wrapped in a filter paper and put into the extraction chamber of the soxhlet, for effective extraction of the oil, the n-hexane (400ml) was administered through the top of the condenser with the aid of a funnel, the solvent passed through the condenser to the extraction chamber and finally settles at the round bottom flask mixing up with the anti-bumping. After inspecting the setup, the heating mantle (water bath) was put on, and setting the mantle to the boiling point of the n-hexane. As the n-hexane begins to boil, it evaporates from the round bottom flask through the extraction chamber which

contains the sample and finally the condenser containing the water that cools the system traps the n-hexane and condenses it and it drops as liquid back into the extraction chamber and as the liquid n-hexane increases in volume in the extraction chambers it reaches the siphon point and then siphon back into the round bottom flask, this process continues until the n-hexane in the extraction chamber becomes colourless, which indicates that the oil in the sample has been extracted and the separated oil is put into the rotary evaporator to gently and efficiently remove the solvent from the sample by evaporation at reduced pressure. This process is repeated until the required volume of the essential oil was obtained from the extraction process.

2.2.3. Soya Bean Husk Oil and Orange Peel Orange Physico-Chemical Properties

Free Fatty Acid Determination

0.125g of sample was measured and poured into conical flask. 25ml of hot ethanol was added to the mixture, which was then boiled together and was gently stirred simultaneously. Three (3) droplets of phenolphthalein indicator were also included into the mixture, which was titrated with NaOH standard solution of 0.04M until a pink colour was obtained.

Free acid content was determined using equation;

$$\text{Lipid FFA} = \frac{V \times F \times M}{10 \times W} \quad (1)$$

V = NaOH volume used;

F = equivalent weight of FFA expressed in oleic acid (2.83g);

M = molarity of NaOH and W = weight of NaOH.

2.2.4. Acid Value Determination

25ml diethyl ether was mixed with 25ml of alcohol and 1ml of phenolphthalein solution and was carefully neutralised with 0.1ml sodium hydroxide. 10g of the oil was dissolved in the mixed neutralised solvent and was titrated with aqueous 0.1ml sodium hydroxide and agitating the mixture until a pink colour which persisted for 15second was obtained.

Hence

$$\text{Acid Value} = \frac{\text{Titre value} \times 5.61}{\text{weight of oil}} \quad (2)$$

2.2.5. Saponification Value Determination

20g of the extract (oil) was weighed into a conical flask and 25ml of alcohol potassium hydroxide solution was added. A reflux condenser was attached and the flask was heated in boiling water for 1hour and it was constantly agitated and 1ml of phenolphthalein solution was added and was titrated and a blank was also done at the same time

$$\text{Saponification Value} = \frac{\text{Blank} - \text{titre} \times 28.05}{\text{weight of oil}} \quad (3)$$

Where blank and titre value are in ml and weight of oil in grams.

2.2.6. Iodine Value Determination

Wij's solution

8g of iodine trichloride was dissolved in 200ml of glacial acetic acid and 9g of iodine was also dissolved in 300ml carbontetrachloride. The solutions were mixed and diluted to 1000ml with a glacial acetic acid. The extract (oil) was poured into a small beaker and a suitable quantity the sample was weighed by difference into a dry glass Stoppard bottle at about 250ml capacity. The approximate weight in g of the extract to be taken was calculated by dividing 20 by the highest expected iodine value, then 10ml of carbon tetrachloride was added to the oil and dissolved. 30ml of wij's.

A conical flask was used to weigh 0.4 g of the sample with 20ml of chloroform which was added to dissolve the oil. 25ml Wij's solution and 20 ml of 10% KI were subsequently added to the mixture; the flask was shaken and then kept in the dark for a period of 30 minutes at temperature below 30°C. This mixture was later titrated with a 0.1M of Na₂S₂O₃ solution until the yellowish colour nearly disappears. Some droplets of 1% starch indicator was added to the mixture. More drops of Na₂S₂O₃ were still added to the titration and shaken vigorously until blue coloration disappears.

$$\text{Value of Iodine} = \frac{12.69C (V_2 - V_1)}{M} \quad (4)$$

C = Na₂S₂O₃ concentration used;

V₁ = Na₂S₂O₃ volume used for blank titration;

V₂ = Na₂S₂O₃ volume used for determination.

M = Sample mass

2.2.7. Peroxide Value Determination

1gram of the extract (oil) was measured into a clean dry boiling tube and 1gram of powdered potassium iodide was added. A 20ml of solvent mixture (10ml of glacial acetic acid+ 10ml of chloroform) was added to the initial solvent in the clean dry boiling tube. The tube was placed in boiling water and allowed to boil for 30 seconds and vigorously for another 30 seconds. The content was poured quickly into a flask containing 20ml of potassium iodide solution and 0.002M of sodium thiosulphate was titrated using starch, a blank was prepared at the same time.

The peroxide value is calculated thus

$$\text{Peroxide value} = \text{Titre value} \times 2 \text{ in eq/kgmax.} \quad (5)$$

2.2.8. Density and Specific Gravity Determination

Crude oil specific gravity was determined using the hydrometer method.

10ml of refined extract was weighed with a 10ml density bottle and recorded.

$$\text{Density} = \frac{\text{Mass of the oil (g)}}{\text{Volume of the oil (cm}^3\text{)}} \quad (6)$$

Specific gravity:

$$\text{Specific gravity} = \frac{\text{Density of oil}}{\text{Density of water}} \quad (7)$$

API Gravity

API gravity (29°C) calculated using the relationship

$$\text{API gravity} = \frac{141.5}{\text{SG}} - 131.5 \quad (8)$$

Wax Content

The standard acetone method (UOP 46-64 method) was used to obtain the percentage of wax in the crude oil samples. A sample of the crude oil was measured and weighed into a 100ml beaker. Then 25ml of toluene was

added to the sample and stirred for 5 minutes. Again 5g of fuller's earth (aluminium silicate) was weighed and added to the mixture to make the sample clear of all polar materials in the oil. Subsequently, the toluene was removed from the sample by evaporation in the oven at 45°C. Then, the deposit was redissolved in ether-acetone mixture in a ratio of 3: and was put into a freezer at -17°C for two hours. Then, the solution was filtered through a filter paper which was already weighed. The filtrate (precipitated wax) on the filter paper was dried in an oven at 45°C. The wax content was determined using the formula:

$$\text{Wax content} = \frac{(\text{weight of filter paper} + \text{precipitated wax}) - \text{weight of empty filter paper}}{\text{weight of oil measured}} \quad (9)$$

Pour Point

Pour point was determined by ASTM D5853-17a – standard test method for pour point of crude oils (procedure A). Pour point test jar with cork and thermometer was filled to match with waxy crude oil samples (40ml). The samples was heated to 60°C and then placed in a cooling jacket of a sets cloud point and pour point refrigerator. The samples were observed for flow every 3°C drop in temperature the pour point was determined from where the liquid was converted from Newtonian to a non-Newtonian liquid.

2.2.9. Performance Evaluation of Soya Bean Husk Oil and Orange Peel Oil as Wax Inhibitors on Waxy Crude Oil

10ml of the crude oil sample was poured into 27 different sample bottles, which was then dosed with dosed with individual and combined pour-point depressants using micro-syringe at different dosage concentrations 700ppm, 1400ppm, 2100ppm and 2800ppm. The effect of the inhibitor on the sample of crude-oil pour-point and viscosity was evaluated.

3. Results and Discussion

Table 7. Characteristic properties of waxy crude oil samples.

Waxy crude oil sample	Pour point(°C)	Pour point(°F)	Specific gravity	Api gravity	Wax content (%)
A	27	80.60	0.83	38.39	14.40
B	30	86	0.86	33.00	15

The table above shows the characteristic properties of the waxy crude oil samples used for this experimental study.

Table 8. Characteristic properties of the plant extract.

Properties	Soya Bean Husk Oil	Orange Peel Oil
Iodine Value (Wij's)	117.14	103
Saponification (mgKOH/g)	191.75	183
Acid Value (mgKOH/gmax)	10.6	4.2
Peroxide Value (mEq/kgmax)	1	8.42
Density (kg/m ³)	840	91.2
Specific Gravity	0.84	0.912

Table 9. No Flow Temperature (°F) for Crude Oil sample A doped with inhibitor.

(ppm)	C+SBHO	C+OPO	C+T
700	75.5	75.5	75.5
1400	69.8	75.5	75.5
2100	69.8	53.6	75.5
2800	75.5	64.4	75.5

Table 10. No Flow Temperature (°F) for Crude Oil sample B doped with inhibitor.

(ppm)	C+SBHO	C+OPO	C+T
700	69.8	69.8	69.8
1400	64.4	69.8	69.8
2100	64.4	53.6	69.8
2800	69.8	59	69.8

Table 11. Pour Point (°F) for Crude oil sample A doped with inhibitors.

Ppm	C+SBHO	C+OPO	C+T
700	80.6	80.6	80.6
1400	80.6	80.6	80.6
2100	69.8	64.4	80.6
2800	80.6	69.8	80.6

Table 12. Pour Point (°F) for Crude oil sample B doped with inhibitors.

PPM	C+SBHO	C+OPO	C+T
700	75.5	75.5	75.5
1400	69.8	75.5	75.5
2100	69.8	59	75.5
2800	75.5	64.4	75.5

Figure 1 shows a plot of pour point temperatures of the waxy crude oil doped with soya bean husk oil at different concentration (ppm). The plot shows that the optimum concentration of the inhibitor is at 1400 ppm and 2100 ppm respectively for both crude oil A and B which implies that below and above these concentrations the inhibitor will not perform effectively. The inhibitor depressed the pour point temperature of the waxy crude oil by 37.4°F and 42.8°F respectively which implied that the inhibitor depressed more in crude oil sample B.

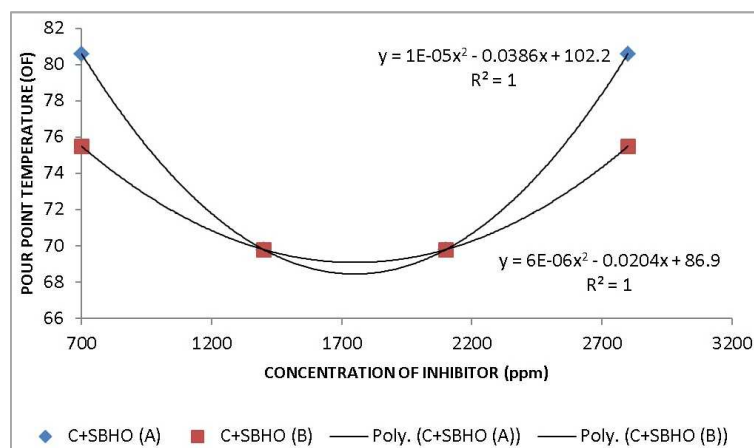


Figure 1. Plot pour point temperature (°F) vs crude oil sample A&B plus soya bean husk oil (ppm).

Figure 2 below it could be seen that the inhibitor performed well at a concentration of 2100 ppm in both crude oil samples A & B, which is adjudged to be the optimum inhibitor concentration that will yield the best result in term of the pour

point that is under consideration. Again, below or above this concentration, the developed wax inhibitors will not perform optimally and the developed wax inhibitor depressed the waxy crude oil A & B by 53.6°F and 59°F respectively.

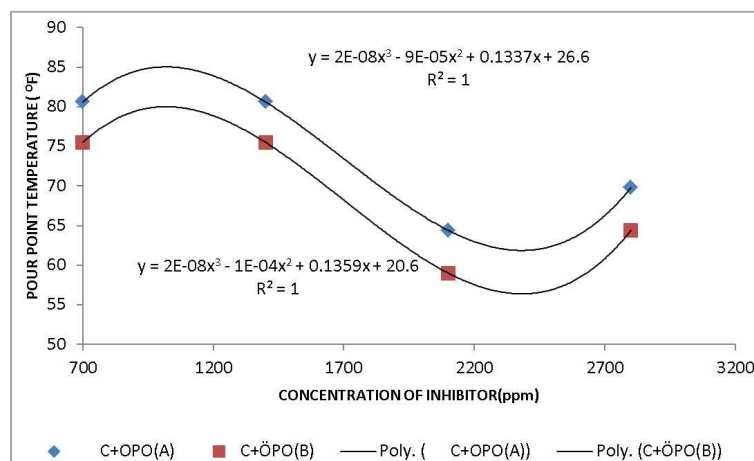


Figure 2. Plot pour point temperature (°F) vs crude oil samples A & B plus orange peel oil (ppm).

Figure 3 below, it could be deduced that the optimum inhibitor concentration was at 700 ppm, above which the inhibitor will not perform. Nevertheless, increasing the concentration of this inhibitor will only lead to a waste of

resources, because the depression impression on the crude oil showed no depression in crude oil sample A but depressed crude oil sample B by 42.8°F.

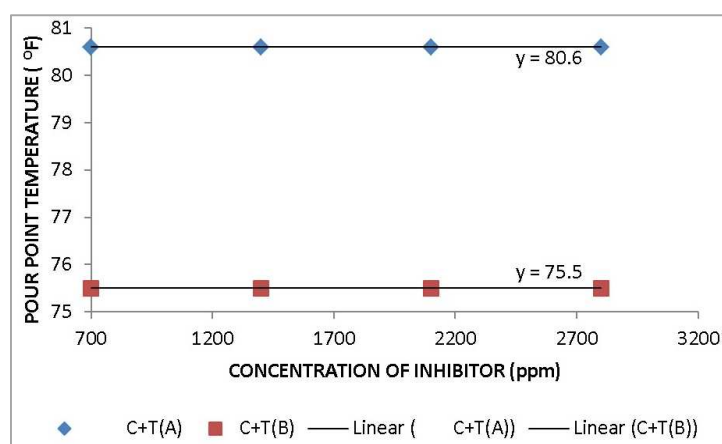


Figure 3. Plot of pour point temperature (°F) VS Crude Oil samples A & B plus Toluene (ppm).

The figure 4 below showed the pour point temperatures of the wax inhibitors (additives) on the concentration of the additives in parts per million (ppm) of the waxy crude oil sample A. Again the OPO wax inhibitor performed best

amongst the three wax inhibitors used for this study by depressing the waxy crude oil sample by 53.6°F at its optimum concentration followed by SBHO wax inhibitor at 37.4°F and T at 32°F respectively.

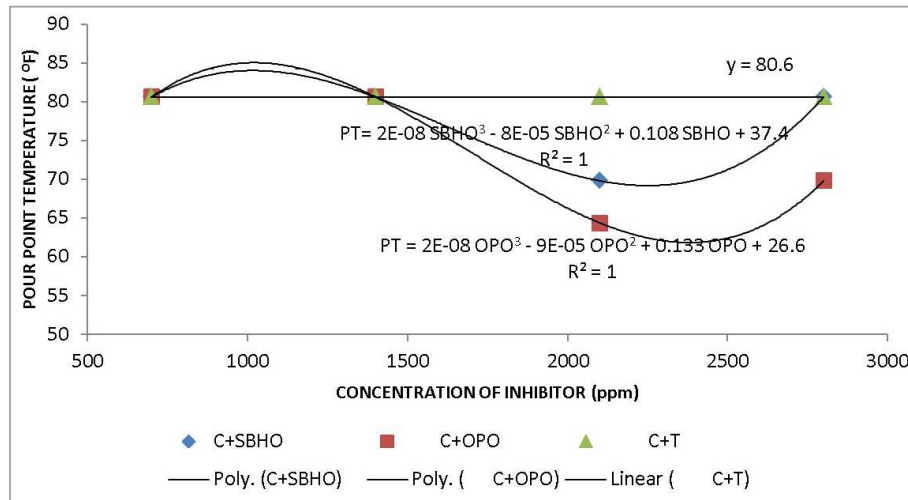


Figure 4. Plot of pour points temperature (°F) versus inhibitors concentration (ppm) for crude oil sample A.

Figure 5 below showed the pour point temperatures of the wax inhibitors (additives) on the concentration of the additives in parts per million (ppm) of the waxy crude oil sample B. Again the OPO wax inhibitor performed best amongst the three wax inhibitors used for this study by

depressing the waxy crude oil sample by 59°F at its optimum concentration of 2100 ppm followed by SBHO wax inhibitor at 42.8°F at 1400ppm and 2100 ppm and T at 37.4°F at 700ppm through 2800 ppm respectively.

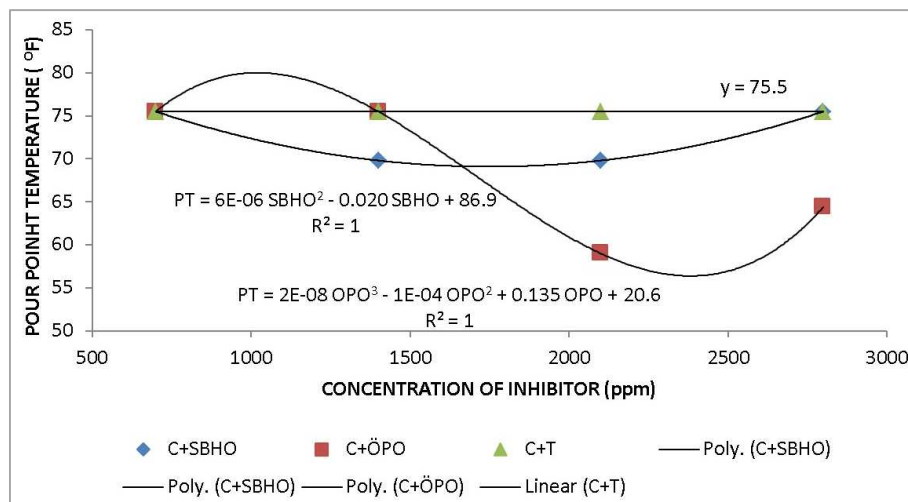


Figure 5. Plot Of Pour Points Temperature (°F) Versus Inhibitors Concentration (ppm) For Waxy Crude Oil Sample A.

Figure 6 showed the point on the plot where the crude oil samples ceased to flow. At these respective temperatures the waxy crude in the horizontal flow line is completely waxed up. For the above inhibitors to function properly, the flow line should be maintained above the wax appearance temperature of the waxy crude oil.

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line should be maintained above the wax appearance temperature of the waxy crude oil.

Figure 8 the plot of waxy crude oil sample doped with Orange peel oil depressed the crude oil sample A & B up to 59°F at 2100 ppm followed by Soya Bean Oil with a depression of 48.2°F at 1400 ppm and 2100 ppm for sample B and 37.4°F at 1400 ppm and 2100 ppm for sample A and then lastly with toluene causing a depression of 42.8°F at 700 ppm through 2800 ppm for crude oil sample B and no effect of toluene in crude oil sample A.

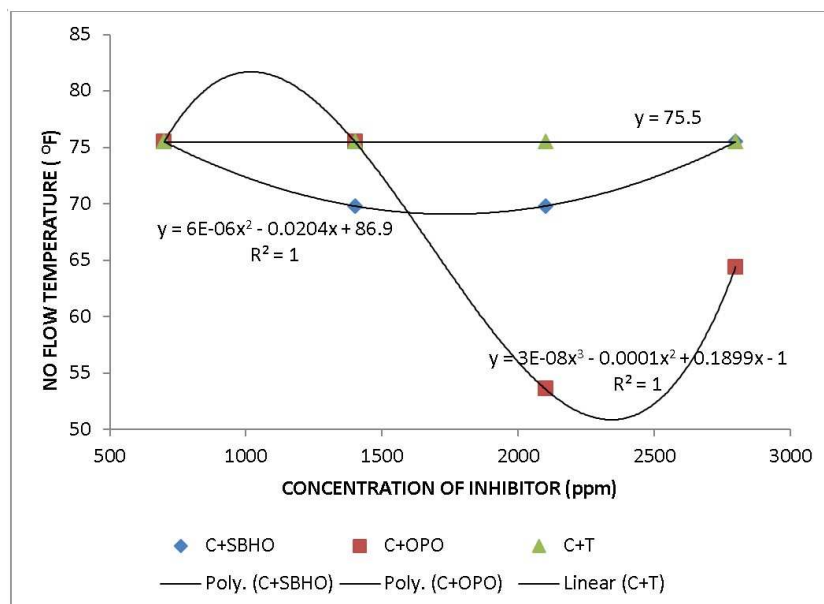


Figure 6. Plot of No flow temperatures (°F) versus inhibitors concentration (ppm) for crude oil sample A.

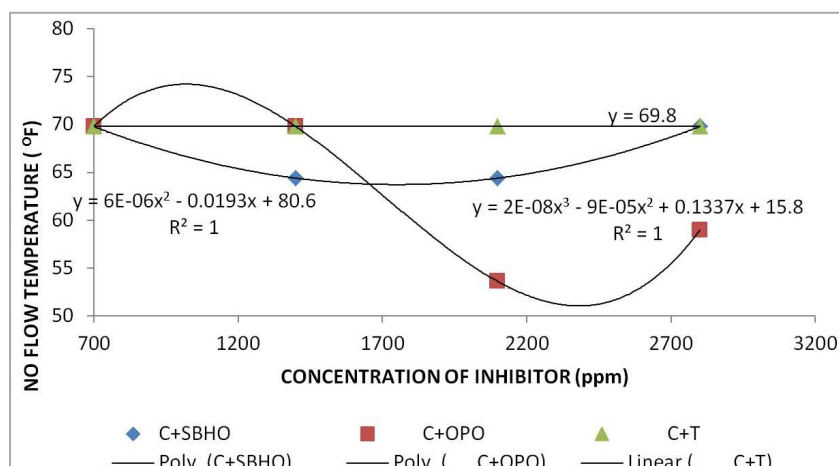


Figure 7. Plot of No flow temperatures (°F) of inhibitors versus inhibitors concentration in ppm for crude oil sample B.

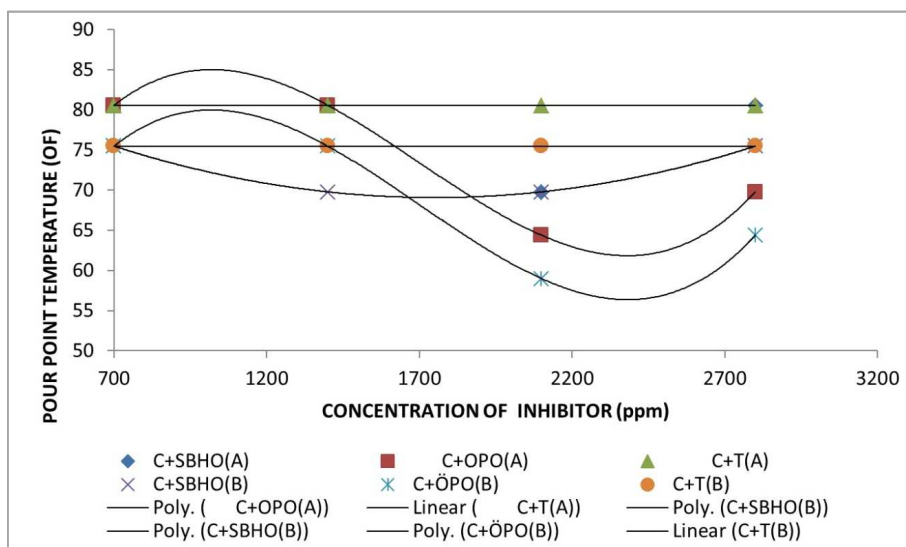


Figure 8. Plot of pour point temperature (°F) versus inhibitor concentration (ppm) for waxy crude oil samples A & B.

4. Conclusion

Pour point depressants was developed using locally sourced non-edible orange peel and soya bean husk. The solvents (oils) were applied on the waxy crude oil samples to determine the pour point of the crude oil was determined from where the liquid was converted from Newtonian to a non-Newtonian liquid.

The pour point for waxy crude oil without depressant, waxy crude oil doped with soya bean oil, waxy crude oil doped with orange peel oil and waxy crude oil doped with Toluene for crude oil sample A were 105°F, 69.8°F, 64.4°F and 80.6°F and for crude oil sample B were 105°F, 69.8°F, 59°F, and 75.5°F respectively. This result provides an insight on how the crude oil flows. This implies that the higher the wax content of the sample, the easier the wax appearance. A similar result was reported by Bai and Zhang (2013). The results between local pour point depressants and toluene on waxy crude oil samples were compared. It was observed that OPO depressed the crude oil most and could be used as pour point depressant.

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