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Experimental Study of Utilization of Plant Seed Oil as Pour Point Depressant for Nigerian Waxy Crude Oil

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Abstract - Wax deposition has been of great concern in flow assurance during crude oil production and transportation. Pour point depressants (PPDs) are used as chemical additives when transporting crude oils at temperatures below their wax appearance temperatures (WAT) to prevent this wax deposition problem. Various chemical additives used so far are synthetic products and quite expensive. This study investigates the utilization of natural plant seed oil extracted from rubber seed (RSO), jatropha seed (JSO) and castor seed (CSO) as PPDs for Nigerian waxy crude oil. Effects of triethanolamine (TEA) on pour point of the crude oil samples were also investigated for comparative purposes. The results obtained revealed that the seed oils could depress the pour points of the crude oil appreciably while CSO exhibited highest depression ability of about 11oC at 0.3%v/v doping with additive. JSO however, exhibited similar pour point depression ability of 11oC at 0.4%v/v addition. CSO and JSO which performed better than the TEA could be a good substitute for the chemical depressants.

Keywords - plant seed oils, pour point depressant, transporting crude oils, triethanolamine, wax deposition.

1.0 Introduction

Paraffin wax in crude oil exists, at typical reservoir temperatures (70–150°C) and pressures (>2000psi), as liquids, and precipitate out as solids and deposit on walls of pipes, as the temperature and pressure decrease [12], [5], [11], [15], [13], [5], [3]). This phenomenon is of particular concern 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 [22], [11], [6]. Paraffin deposition in trunk lines and transmission lines exposed to cooler climatic conditions remains an expensive aspect of getting oil to the market [12]. For instance in Nigeria, pipelines (e.g. Ezombe, 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], [1]. In 2007, 1500bpd was deferred due to wells closed in as a result of wax problems in Niger Delta crude oil field of Nigeria [18]. 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 [17], [14]. 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 [11], [20], [21].

From the foregoing it is thus clear that the avoidance or remediation of wax deposition is one key aspect of flow assurance [7]. Many of these problems can be effectively resolved by the appropriate application of pour point depressing chemicals. Crude oil pour point depression is significant in eliminating paraffin wax deposition [1] and is crucial for assessment of flow behavior and storage of crude samples. This study is therefore designed to investigate the use of natural plant seed oil as pour point depressants for Nigeria waxy crude oil and compare their effectiveness with the impacts of the previously tested triethanolamine on the crude oil. The plant seeds being considered are naturally non-edible seeds which may be regarded as agricultural wastes from: rubber plant (*Hevea brasiliensis*), jatropha plant (*Jatropha curcas*) and castor plant (*Ricinus communis*).

2.0 Materials and Methods

Two waxy crude oil samples A and B, obtained through the Department of Petroleum Resources (DPR) from oil fields in Niger Delta region of Nigeria were used in this study. The seed oils were extracted from seeds obtained from farm locations in Epe and Ikire within the Southwestern region

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of Nigeria while the triethanolamine used was analytical grade products of BDH Chemical Ltd, Poole England. Solvent extraction was used to extract the oil from the seeds using a Soxhlet extractor with *n*-hexane (800 ml) as the solvent as described by [4] and fatty acid composition analysed using gas chromatography. The seed oils extracted and tested were rubber seed oil (RSO), jatropha seed oil (JSO) and castor seed oil (CSO). Impact of triethanolamine (TEA) on the samples pour points was also tested for comparative purpose.

Each crude oil sample was reconditioned by heating it to a temperature of about 60°C for nearly 10hr in an oven, with hand-rocking occasionally during heating in the laboratory prior to experiments to erase any previous thermal history that might exist in such sample. 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 sample for testing. The reconditioned crude oil samples were characterized by determining their paraffin composition using an Agilent Technologies 6890N gas chromatograph equipped with a flame ionization detector (FID), specific gravity (S.G.) and American Petroleum Institute (API) gravity using the ASTM D287 standard, wax content using precipitation method reported by [13] and pour points using the portable Pour Point Tester PPT 45150 by PSL SystemTechnik, which is a compact lab-instrument for measuring the pour point of oils and oil products. PPT 45150 has an accuracy of ± 0.1°C. The average carbon numbers of the crude oil samples were calculated from compositional analysis using ASTM D2887. The asphaltene content of each crude oil sample was determined using ASTM D3279 while the sulphur content was determined using ASTM D4294.

For each run of the experiment the pour points of samples were obtained by heating each sample to 35°C and then poured into the hollow tubing connected to the internal cooling device of the PPT 45150. The pour points were identified by the tester based on the flow-temperature characteristics of the fluid. A sensing head for crude oil and inhibited crude oil in the device determined the pour point temperature and the value displayed on the screen of the tester recorded. The procedure was carried out on the pure crude oil samples as the reference point. Each chemical additive was added to crude oil sample at the concentrations of 0.1%v/v, 0.2%v/v, 0.3%v/v and 0.4%v/v for subsequent tests of the additives on the pour points of the crude oil samples. The impacts of the seed oil additives on the rheological properties particularly the viscosities, of the crude oil samples were also determined using the Fann rotational viscometer as described by [4].

3.0 RESULTS

The results of the fatty acid composition analysis on the seed oils showed that oleic acid compositions of the oils are 18.3%, 43.11% and 4.73% for RSO, JSO and CSO respectively. The linoleic acid components are 38.2%, 39.12% and 2.96%. The CSO contained 89.3% ricinoleic acid which neither RSO nor JSO contained. Also, RSO contained 24.1% linolenic acid which was absent in JSO but a trace of 0.2% in CSO. The specific gravity of the extracted seed oils were found to be 0.93, 0.96 and 0.91 for RSO, JSO and CSO respectively. The results obtained showed that the APIg of the samples are 35° for A and 29.7° for B. Sample B has higher wax content of 30.71% and lower pour point of 7°C (Table 1). The average carbon number of the crude oil samples indicated that sample A contain higher composition of lower hydrocarbons than the higher hydrocarbons (above C_{18}) when compared with sample B and this is reflected in their wax content observed (Table 1 and Figure 1).

Table 1. Characteristic Properties of Crude oil Samples

Samples	Pour point (°C)	APIg	Wax content (%)	Average Carbon Number	Sulphur content (wt%)	Asphaltene content (wt %)	Viscosity at 40°C (mPa.s)
A	10	35.0	8.44	14.1	0.08	0.03	2.86
B	7	29.7	30.71	21.7	0.11	0.16	18.67

The pour point of sample A decreased as the concentration of chemical additive doped increased from 0.1% to 0.3% for the three plant seed oils while the pour point of sample A was not further affected by addition of TEA to the sample beyond 0.2% as shown by Figure 2. Beyond 0.3% addition of any of the seed oil did not have any impact on the crude oil sample. It was observed that the CSO depressed the sample A most with the depression of about 8.5°C while RSO and JSO depressed sample A by 8°C at 0.3% doping. The TEA had the least depression on sample A, though it exhibited similar trend of impact on the sample as RSO at concentration between 0% and 2%. Thus, TEA is effective pour point depressant at very low concentration while the seed

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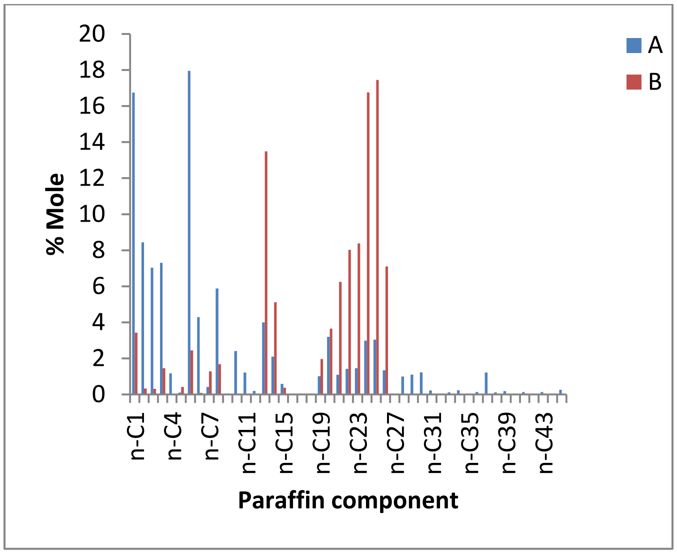

Figure 1. Paraffin composition of crude oil samples A and B

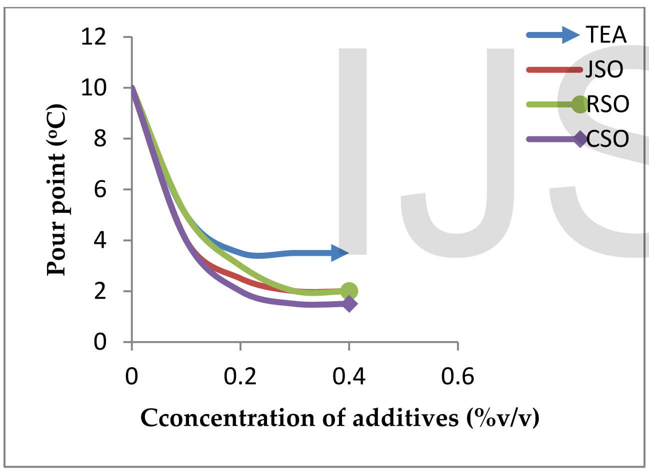

Figure 2 Effects of variation of additive concentration on pour point of sample A

oils could perform better at same concentrations of doping and above for sample A. This is in agreement with the observation of previous researchers [19], [16], [4]. The chemical additives may have interacted with the paraffin molecules in the crude oil samples thereby modifying the size and shape of wax crystals and inhibit the formation of large wax crystal lattices [22], [3]). This may be attributed to the fact that the chemical additives molecules can actually bind to the larger paraffin molecules in solution and thereby sequester them from being available for wax aggregation and deposition. As a result, the altered shape and smaller size of the wax crystals reduce the formation of the interlocking networks and reduces the pour point [10] by preventing wax agglomeration [9], [3].

It was observed from Figure 3 that CSO and JSO have similar trend of effects and highest positive impact on sample B pour point at low concentration (0.1%) and afterward CSO

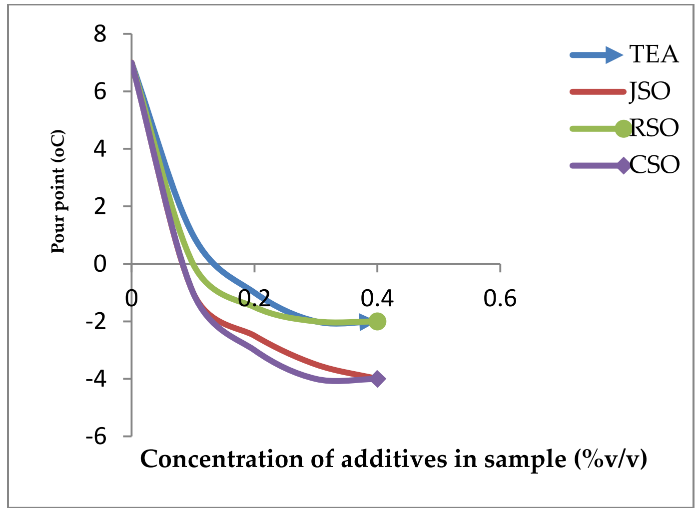

Figure 3 Effects of variation of additive concentration on pour point of sample B

the pour point at a higher rate than the JSO. At 0.4% chemical additive dosage JSO and CSO have the same effect on sample B pour point (depressed to -4°C). TEA had the least impact on the pour of sample B when doped at concentration below 2.5% but exhibited similar trend of impact with RSO on the sample B at concentration of 2.5% and above. Where the wax content of the sample being tested has been taken care of by the little quantity of the additive further addition will have no effect on the pour point of the sample. It could therefore be said that the degree of depression caused by the addition of chemical additives to the pour point of a waxy crude oil sample depend on the quantity of paraffin wax in the sample and their molecular distribution. The high percentage of oleic acid in the JSO and ricinoleic acid (hydroxyl derivative of oleic acid) in CSO containing hydroxyl polar group may have given them edge over RSO in their performances as flow improvers in depressing the pour point. This is in agreement with findings of [4]. Oxygen containing groups in seed oils take the role of inhibiting the growth of waxes and poisoning them by adsorptive surface poisoning mechanism.

The impacts of the seed oils on the viscosity of crude oil sample A is shown in Figure 4, which revealed that the seed oils were able to reduce the viscosity of the crude oil sample when the doping percentage was between 0.1 and 0.2%. JSO addition caused the highest reduction of sample A at 0.2% concentration. Addition of seed oil additives beyond 0.3% caused increase in the viscosity of the crude oil sample. Similarly Figure 5 revealed that the seed oil additives

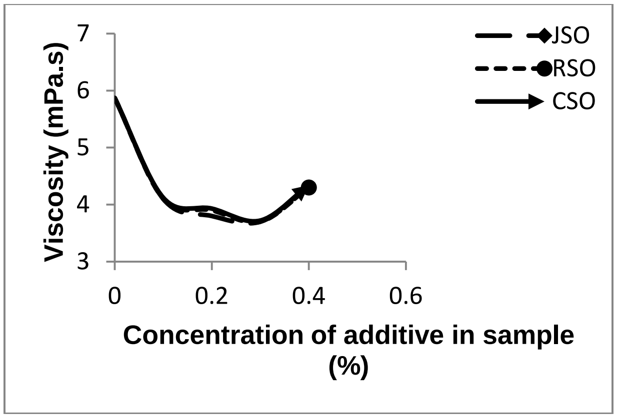

Figure 4 Effects of Chemical additives on Viscosity of sample A at 30°C

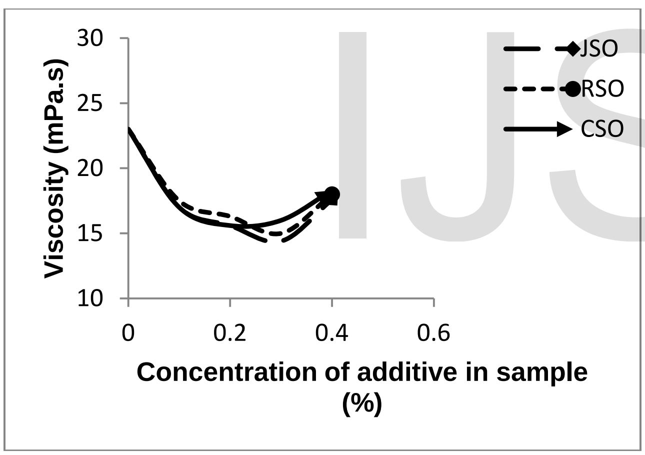

Figure 5 Effects of Chemical additives on Viscosity of sample B at 30°C

reduced the viscosity of sample B at low additive concentrations (0.1 to 0.2% v/v) and caused the viscosity when added to the crude oil sample B beyond 0.3%. Both JSO and CSO reduced the viscosity of sample B equally and more than RSO at 0.2% concentration. These implied that the plant seed oil component interacted with components of crude oil samples especially their paraffins and asphaltenes which resulted in the reduction of their viscosities. This is in agreement with the findings of [4]. Hence, the plant seed oils at low concentrations are capable of improving the flow ability of the waxy crude oils.

4.0 Conclusion

The impacts of plant seed oils and triethanolamine on the pour points of two waxy crude oil samples were investigated. 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 which performed better than the RSO could be used as pour point depressant in waxy crude oil. 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.

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