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Viscoelastic behavior and its effect on pumping energy under the influence of petroleum extract

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***Abstract*— The aim of this study is to determine how the aromatic compound tetrahydrofuran affects the rheological behavior of the oil and the percentage of energy consumption during the pumping process at 20, 30 and 50°C. In this study, the chemical additive was added at concentrations of 3000, 6000 and 9000 ppm. The AR-2000 rheometer of the TA instrument was used for rheological modeling, measurement of viscosity, yield point, and viscoelastic characteristics of crude oil. The results obtained show that tetrahydrofuran has a significant effect on rheological parameters and pumping energy during oil flow. With the addition of additives, the viscosity of crude oil decreased more than 34%, the power consumption of the pump by 26.90%. At a concentration of 9000 ppm, the yield stress is reduced more than 41%. The effect of the compound is significant at low shear rates, where the behavior is non-Newtonian, then decreases with increasing shear rates, where the behavior becomes Newtonian. The addition of tetrahydrofuran shows a greater effect on the greater viscous modulus compared to the elastic modulus and the crude oil has the characteristic of a viscous liquid.**

***Keywords*— viscoelastic behavior, emulsions, viscosity, yield stress.**

I. INTRODUCTION

Due to rising energy demand and the price of a barrel of oil, oil companies have increased production in the oil fields and moved oil over very long distances to export points. The viscosity of the oil causes several problems for this process. Most of the time, researchers solve these problems by adding additives that make the oil less viscous [1, 2]. It is known in the scientific community that wax and asphaltene are responsible for oil viscosity [3-5], which is why there are many scientific studies that study the effect of additives on these two compounds. Researchers Machado et al [6] , Li et al [7] ,and Marenov et al [8] examined the impact of polymers and co-polymers on oil viscosity by focusing on the wax contained in oil, and they found that the compounds do have an influence in lowering viscosity, but only at low temperatures. The researchers Wang et al [9] researched the wax removal effect caused by the addition of ochrobactrum and came to the conclusion that the additive has the potential to break down wax components found in crude oil. Researchers [10-13] investigated the effect of nanoparticles. These authors proved that the addition of these additives limits the superposition of asphalt particles, which results in a reduction in the viscosity of the oil. Positive results [14, 15] were obtained by who used materials of vegetable origin to reduce oil viscosity. However, the short shelf life of these additives is a major challenge. Many scientists have experimented with various solvents in an effort to lessen oil's viscosity. Xylene and cyclohexanone were utilized by Minale et al [16]. The addition of 20% kerosene, xylene, toluene, naphtha, and heptane were tested to see how they affected oil viscosity in a study by Fakher et al [17]. Ilyin et al [18] investigated the effects of heptane, pentane, and hexamethyldisiloxane at concentrations as high as 40%.A research on the influence of para-xylene on a solution was carried out by Moncayo-Riascos et al [19] , and it includes a variety of wax/asphaltene ratios in the solution being tested. Fred et al [20] conducted research to investigate how adding xylene to a mixture that also contained linseed oil and biodiesel affected the viscosity and pour point of Nigerian petroleum. It is important to note that the effects of these additions on oil viscosity vary depending on the chemical selected, the concentration employed, the temperature at which the compound is evaluated, and the compound treated [21] **.**The fact that these chemical additives are only effective when added in extremely large concentrations is the major negative associated with them. Meriem-Benziane et al [22], while their advantage is compound polarity, which interacts with asphalt polarity to prevent asphalt aggregates, which are probably responsible for oil viscosity [23, 13]. The first objective of this research is to find a way to reduce the pumping power during the process of transporting crude oil by using the tetrahydrofuran compound. For this, we first studied the effect of tetrahydrofuran on energy losses as well as pumping energy during the oil transportation process. Third, it's to understand the effect of additive on the internal structural properties of crude oil by studying the viscoelastic behavior.

II. MATERIALS AND METHODS

The southern region of Algeria is the source of the oil examined. This particular oil has an API gravity of 36.25, a specific gravity of 0.837 at 25°C, an asphalt volume of 1.5% and a wax volume of 10.15%. To prepare the samples for study, 3000 ppm, 6000 ppm, and 9000 ppm chemical compounds were added to the oil. In this investigation, the AR-2000 rheometer of the TA instrument was used for rheological modeling, measurement of viscosity, yield point, and viscoelastic characteristics of crude oil.

III. EXPERIMENTAL PROTOCOL

The sample to be examined (crude oil/additive) is stirred for 5 min with a magnetic stirrer before being placed in the rheometer's container and exposed to a precision of 100 (s^{-1}) to make the mixture uniform around the geometric measurement [1]. The samples is then put through a period of resting that lasts for 10 seconds, and the process of calculating begins as soon as the resting period concludes. The sample is subjected to a pre-share in the range of 0.01 to 300 (s^{-1}). At temperature 20, 30 and 50°C the effects of additive was studied on viscosity, yield point, storage modulus, loss modulus, pressure drops and pump consumption.

A. Effects of the additive on pressure drops and pump consumption at 300 s-1

Viscosity is the measurement of the fluid's internal friction, which is the main reason why energy is lost when pumping oil from one place to another [2]. When oil is produced or transported, pressure drops and power consumption are two of the biggest problems for oil companies. White et al equations [3], Singh et al equations [4], Eqs.3a through 3c make it possible to calculate the pressure drop as well as the consumption of a pump with an efficiency of 0.85.The results obtained with and without the additive are shown in the following table 1.

$$\tau_w = \mu\,\gamma \qquad (3a)$$

$$\Delta P = 4\,\tau_w \frac{l}{d} \qquad (3b)$$

$$P = 18.18\,\frac{\Delta P}{\eta} \qquad (3c)$$

Where τ is shear stress (Pa), ΔP pressure drop (Pa), ηis efficiency of pump and P is consumption of a pump (WattS).

After reviewing the data that were acquired, it is clear that there has been a considerable decrease in the pressure drop, which has been followed by a reduction in the amount of pumping energy that has been used. Energy consumption drops as a direct result of the compounds' effect on oil viscosity. We have observed that the impacts of the suggested additives on the pressure drop as well as the effect of these compounds on the viscosity of the oil are proportionate to one another. When the oil gets less viscous, the pump needs less energy.

Table1. Pressure drop and power consumption with and without tetrahydrofuran at different temperatures

Concentration (ppm)	pressure drop and power consumption with and without tetrahydrofuran		
	T = 20° C		
	τ_w (Pa)	Δ P (Pa)	P (WattS)
0	1.8954	7.5818	162.1613
3000	1.6352	6.5408	139.8978
6000	1.5302	6.1208	130.9148
9000	1.3855	5.5420	118.5336
T = 30° C			
0	1.4017	5.6070	119.9246
3000	1.3544	5.4177	115.8754
6000	1.2426	4.9705	106.3106
9000	1.1314	4.5258	96.8005
T = 50° C			
0	0.9436	3.7747	80.7343
3000	0.9068	3.6274	77.5845
6000	0.8670	3.4681	74.1785
9000	0.8476	3.3904	72.5155

The results presented in Table 2 shows that at a temperature of 20°C, the percentage of energy reduction used in the pumping reaches its maximum value of 26.90 % when adding 9000 ppm of tetrahydrofuran. At 30°C, we find that the effect of added compounds on yield stress decreases with different concentrations. The highest percentage reduction in pumping energy at this temperature is estimated to be 19.28% at the 9000 ppm concentration. The decrease in compound effect increases with increasing temperature, as the percent reduction in pumping energy reaches 10.18% with the temperature reaching 50°C at the highest concentration of compound added.

B. VISCOELASTIC BEHAVIOR

Through the viscoelastic study, we aim to determine the mechanical properties in equilibrium states of crude oil [5], as well as the effect of the added compound on each of the elastic modulus and viscous. We also aim to determine the relationship between the evolution of each of the elastic and viscous moduli, the viscosity of the crude oil, and the energy consumed during the pumping process. This study was conducted after determining the linear viscoelastic domain, where the stress was determined at 0.2 Pa. The study was carried out under the influence of a temperature of 20°C with and without additive. Figure 1 represents the evolution of each of the loss and storage modulus of the crude oil without any additive at 20 °C as a function of the angular frequency range of 0.1 to 10 rad/s.

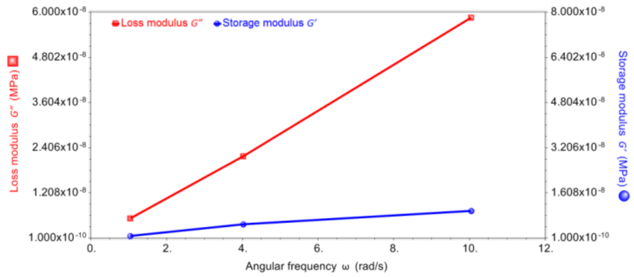

Fig. 1. Loss and storage modulus of crude oil at 20°C.

We note the significant effect of frequencies on the viscous modulus which signifies the amount of energy that was expended in order to get the flow started, which then gets turned into shear heat, where we find a significant increase in the viscous modulus with an increase in frequency. On the contrary, a slight increase in the elastic, which represents the amount of stress energy that was temporarily stored throughout the exam but may be retrieved afterwards, modulus was observed with an increase in frequency. The effect of frequencies on the storage modulus (G') was relatively severe at small frequency values, while this effect decreased at larger frequency values. This is probably due to the reorganization of the asphalt agglomerations. We also notice that the viscous modulus takes values greater than the viscous modulus; the findings are largely consistent with those discovered previously [6]. Based on this conclusion, it may be deduced that the crude oil has the characteristics of a viscous liquid [4, 7].

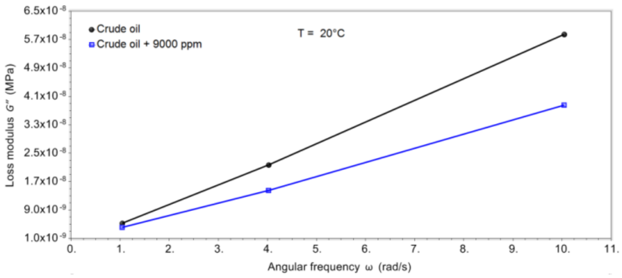

Fig. 2. Loss modulus with and without additive at 20°C.

Figs. 2 and 3 shows the effect of added additive on the storage modulus G' and loss modulus G" at a temperature of 20° C and a concentration of 9000 ppm. There was a considerable influence of the additional additive on the loss moduli G" (Fig. 2), it is fair to say that the inclusion of additive brings about a significant reduction in the level of resistance shown by the material. we also showed a significant drop in the storage modulus G' (Fig. 3). A change significantly by adding 9000 with a lower frequency of 4 rad/s, and this is probably due to a decrease in the energy stored in the fluid due to the effect of the added compound on the viscosity of crude oil.

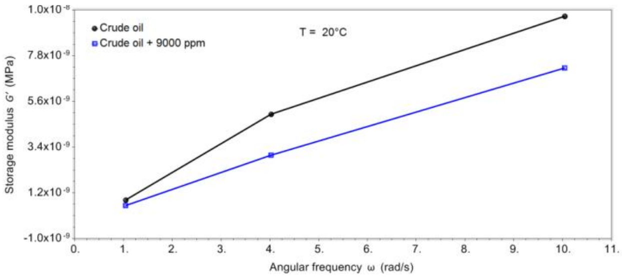

Fig.3. Storage modulus with and without additive at 20°C.

IV. CONCLUSION

From the results obtained, we can conclude that:

- There was a drop in the oil's viscosity and yield stress at all of the temperatures studied for all of the concentrations.
- The samples studied with and without additives behaved like non-Newtonian fluids according to the Herschel-Bulkley model.
- By adding 9000 ppm of additive, we were able to reduce the viscosity by 34%, the yield stress by 41% and the power consumption of the pump by more than 26%.
- The effect of the additive decreases at high temperatures and shear rates.
- A lower efficiency of the added compound at a temperature of 30°C compared to the results obtained at a temperature of 20°C and 50°C
- The loss modulus > the storage modulus and crude oil has the characteristic of a viscous liquid.
- A greater effect of additives on the loss modulus (G") compared to the storage modulus (G').

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