

Improvement of the transportation capacity of the crude oil by the addition of a surfactant agent

DE. Djemiat^a, A. Safri^b, A. Benmounah^c

a. Laboratoire LEGHYD, FGC, Université des Sciences et de la Technologie Houari Boumediene, Bab Ezzouar, Alger, Algérie, email : dj.djemiat3000@gmail.com

b. Laboratoire LEGHYD, FGC, Université des Sciences et de la Technologie Houari Boumediene, Bab Ezzouar, Alger, Algérie, email : absafri@gmail.com

c. UR-MPE, FSI, Université M'Hamed Bouguerra, Boumerdes, Algérie, email : benmounah2000@yahoo.fr

Résumé:

Dans cet article, nous avons étudié l'effet de la concentration d'un tensioactif réducteur de frottement sur les propriétés rhéologiques du pétrole brut algérien. Des mesures ont été effectuées sur la limite d'élasticité, la viscosité apparente, la chute de pression et le débit. Le tensioactif choisi est le toluène. Différentes concentrations de toluène ont été testées (2%, 3% et 6%). Les essais rhéologiques sont réalisés à l'aide du rhéomètre AR2000 de TA Instruments avec une géométrie à cylindriques coaxiaux type Couette. En raison de la grande surface de contact du cylindre, on peut obtenir une bonne précision des mesures à de faibles valeurs de viscosité. Différentes températures ont été testées pour étudier son effet sur les propriétés rhéologiques. Les résultats expérimentaux montrent que le comportement rhéologique du système (huile brut / toluène) est non newtonien à faible taux de cisaillement. On a également noté que l'augmentation de la concentration en tensioactif a un effet sur la viscosité apparente, la limite d'élasticité qui a diminué de façon significative. Les résultats obtenus montrent également que l'augmentation de la concentration de l'additif a également un effet sur la capacité de transport du pétrole brut, l'addition de 6% de toluène a fait augmenter le débit du pétrole brut de 44%.

Abstract:

This article examines the effect of the concentration of a surfactant on the rheological properties of Algerian crude oil, when the yield stress, the apparent viscosity, the pressure drop and flow rate are evaluated. The surfactant choice is Toluene; different concentrations (2%, 3% and 6%) are tested to improve the transportation capacity of Algerian crude oil. The rheological tests are carried out using the rheometer AR2000 from TA Instruments with a coaxial cylindrical geometry type Couette. Because of large contact surface of the cylinder, one can obtain a good accuracy of the measurements at low viscosity values. Different temperatures were tested. The experimental results show that the rheological behavior of system (crude oil / Toluene) exhibits a non-Newtonian behavior at a low shear rate. It was also noted that the increase in the surfactant concentration has an effect on the rheological parameters, the apparent viscosity, yield stress significantly decreased with the addition of toluene. The results obtained also show that the increase in the concentration of the additive also has an effect

on the transport capacity of the crude oil, the addition of 6% of toluene has increased the flow rate of the crude oil by 44%.

Keys words: Crude oil, presser drop, viscosity, yield stress

1 Introduction

It is widely accepted that the rheological parameters affect the crude oil transportation capacity in pipelines [1]. Indeed, the apparent viscosity and the yield stress are important parameters of crude oils, which are critical and necessary parameters in various aspects of petroleum engineering. Accurate data on the viscosity of the oil according to the shear stress and temperature are required for reservoir studies and design of pipelines [2]; improving of these parameters make the production, the treatment and the transport of crude oils easier and less costs. Therefore, it is necessary to reduce the apparent viscosity of crude oil[3]. Currently, various methods of reduction are known to decrease the pressure drop and the viscosity of crude oil. Among them; the two major are the dilution by light crude[4], the other reducing the viscosity by steam injection. Both techniques are much cost; the second produces large quantity of CO₂ emissions. Another solution that is the object of our study is based on the increase of flow in the pipe transportation, the addition of Toluene as a surfactant reducing the apparent viscosity of crude oil, at low concentrations of 2% to 6%.

2 Materials and samples preparations

The crude oil specimens were collected from a reservoir of the TFT sector (Tin Fouye Tabankort/South Algeria). The physicochemical characteristics of the crude oil used are given in Table 1. In order to prepare the studied samples, the crude oil was mixed with different concentrations of surfactant in order to prepare samples of 50ml. For each given surfactant concentration, the sample was subjected to a given temperature (Fresh samples were used for same the temperature).

Table1: sample characteristics of the crude oil used in this study.

Sample characteristic	
American Petroleum Institute(API gravity)	32.7
Liquid density(26°)	0.847
Reid vapor pressure (TVR at 35.5°)	339
Basic sediment and water (BSW %)	0.05

2.1 viscosity reducing agent

Table 2 shows the chemical and physical properties of Toluene. The compound is chosen for their ring type structures. The presence of π electrons in the ring may play a role in the interaction between the compounds added and the π electrons in the polyaromatic systems of the asphaltene agglomerates [5]. A study carried out by Urdahl O et al (1997) [6] on a crude oil shows that crude oils reduction of

viscosity due to the addition of hexane, reveals that hexane will break the molecular associations of asphaltenes with other constituents, and thereby diluting the medium producing lower viscosity.

Table 2: Chemical and Physical Properties of Toluene used.

Chemical and physical properties of Toluene	
Density à 20°C (g/cm³)	0.78
Molar mass (g/mol)	92,14
Boiling point (°C)	110,6

2.2 Experimental procedure and rheological measurements

The rheological properties of crude oil and the system (crude oil / Toluene) were studied using the rheometer AR-2000 TA Instruments. The test procedure used in this study is:

- Initially the crude oil samples are subjected to a pre-shear of 30 s, to erase its memory [6];
- In order to prepare samples of 50 ml; crude oil was then mixed with different concentration of surfactant;
- Initially, the sample will be subjected to a shear rate of 1000 s⁻¹ to erase its memory.
- All the samples are subjected to a pre-shear of 60 s with a shear rate of (0.15 s⁻¹) for a correct homogenization [7, 8];
- The samples are then left to settle for 1min before the acquisition procedure of data is started. The range of the applied shear rate of 0.01s⁻¹ to 500 s⁻¹;
- All the rheometer tests were carried out at low temperature (10 ° C).

3 RESULTS AND DISCUSSION

3.1 RHEOLOGICAL CHARACTERISATIONS

To study the samples of crude oil containing the chosen surfactant, it is necessary at first, to identify the rheological behavior of untreated crude oil. The obtained results of the rheological tests are given in Figure.1 and Figure 2. These figures represents the evolution of the shear stress and the viscosity versus the shear rate, for selected concentrations (2%, 3% and 6%).

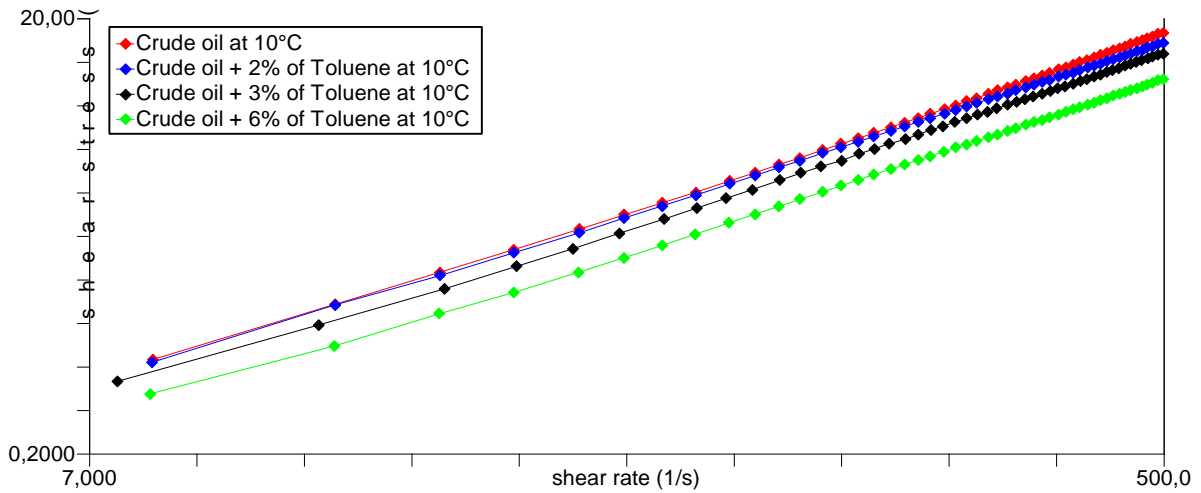


Fig.1: Flow curves of crude oil at different concentrations of Toluene.

The flow curves show clearly the non-Newtonian pseudo-plastic character of the crude oil for chosen temperatures (Fig. 1). Indeed, there is no flow when the applied shear stress is lower than a critical value (called yield value). It can also be observed that the flow curves present similar trends for all the test temperatures, expressed by a progressive increase in the shear stress with the increase in the shear rate. It was also found experimentally that the shear stress and the viscosity decrease with an increase in the surfactant concentration. Moreover, the yield stress also decreases. In Fig.2, the experimental results show the existence of two different regions: one at a low shear rate and the other at high shear rate. The apparent viscosity of the oil decreases significantly in the first region until the shear rate is greater than (400 s^{-1}). While for the high values of shear rate (more than 400 s^{-1}), the apparent viscosity is stabilized and remains constant.

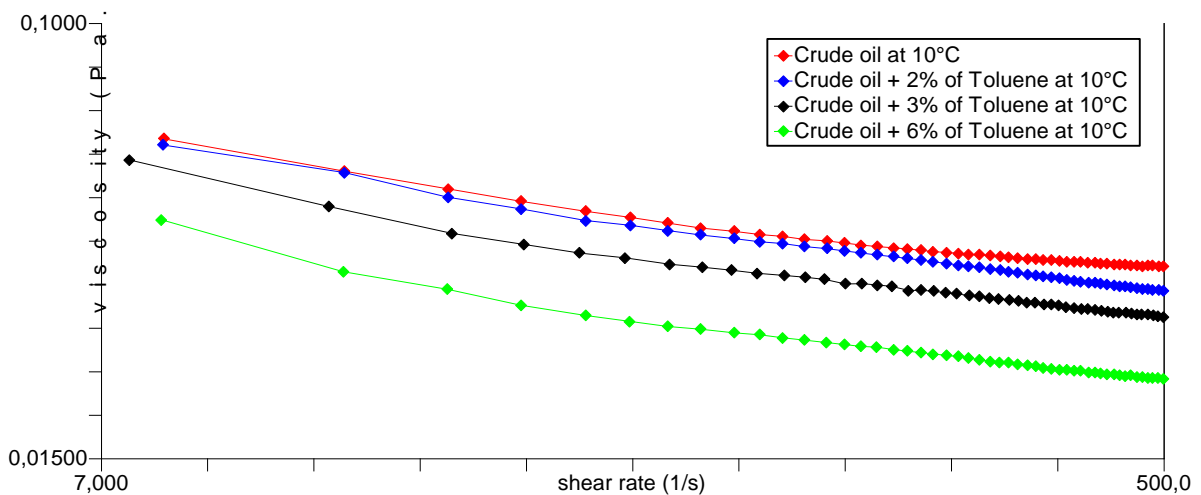


Fig.2: Effect of concentrations of surfactant on the crude oil viscosity

This rheological behavior can be explained by the following considerations: The energy exerted by shear is dissipated in the solution (crude oil / Toluene), which leads to the breaking of these bonds. This leads to the appearance of cumulative deformation of the structure of the raw gel [10, 7]. The second reason is due the presence of π electrons in the ring may play a role in the interaction between the compounds added and the π electrons in the polyromantic systems of the asphaltene agglomerates. The

compounds were kept to one ring to keep the size of the molecules small and allow for a greater diffusion through the crude oil matrix, and penetration into the asphaltene agglomerates [7].

3.2 Modeling of rheological properties

For each concentration tested, the rheological parameters (yield stress, apparent viscosity, and index of structure) are given starting from the adjustment of the flow curves by using the rheological model corresponding to Herschel-Bulkley, which is given in equation 1.

$$\tau = \tau_c + k\dot{\gamma}^n \quad (1)$$

Where: (τ_c): Herschel yield parameter; (k): Consistency index; (n): index of structure

Table3: Rheological parameters in the case of various models.

Concentration of Toluene %	Yield stress τ_c (Pa)	consistency index K (Pa.s)	flow index n
0	0,5442	0,04711	0,9483
2	0,5282	0,04618	0,8666
3	0,4322	0,04014	0,9406
6	0,3788	0,04088	0,8932

An analysis based on the Herschel–Bulkley model was used to determine the rheological parameters at different concentrations. An important reduction in the yield stress was observed for each concentration used of Toluene. In general, the yield stress of crude oil is reduced to one third when the concentration varies from 0% to 6%. We can also notice that there's a threshold consistency index reduction with increasing surfactant concentration.

3.3 Effect of the surfactant to the pressure drop

The shear stress is considered an injection pressure or a crude oil flow in pipelines. Pressure drop value, $E\Delta P$ [10]; in turbulence flow can be calculated by:

$$E\Delta P = n^{0.25} \quad (4)$$

Where n : is the viscosity of the liquid.

These rough calculations can only be used as indicative information for the flow pipelines with crude oil.

Table 4: Changes in the pressure drop as a function of the viscosity for different concentrations.

Concentration %	Shear rate (s ⁻¹)	Viscosity (Pa.s)	EAP (Pa)
0	400	0.03509	0.7692
2	400	0.03210	0.4232
3	400	0.02852	0.4108
6	400	0.02172	0.3838

Table 4 shows the measurements of the pressure drop in the pipeline transportation of crude oil to different Toluene concentrations and for the same shear rate 400 s⁻¹. It can be concluded that the addition of Toluene; caused a diminution of the pressure drop. This reduction can vary up to + 51% by the addition of Toluene in 6% concentration.

3.4 Effect of surfactant on the capacity transportation

Figure 3 reports the measures of shear rate of crude oil at various toluene concentrations at the same shear stress (10 Pa). From equation (5), we can calculate the flow rates corresponding to four values of the shear rate 277.8 s⁻¹, 308.2 s⁻¹, 358.2 s⁻¹ and 500.0 s⁻¹, respectively are in the second region where the crude studied can be described by the Newtonian model.

$$\dot{\gamma} = \frac{4Q}{\pi R^3} \quad (5)$$

Where: $\dot{\gamma}$: shear rate; Q: volume flow rate applied in the cell; R : cell radius

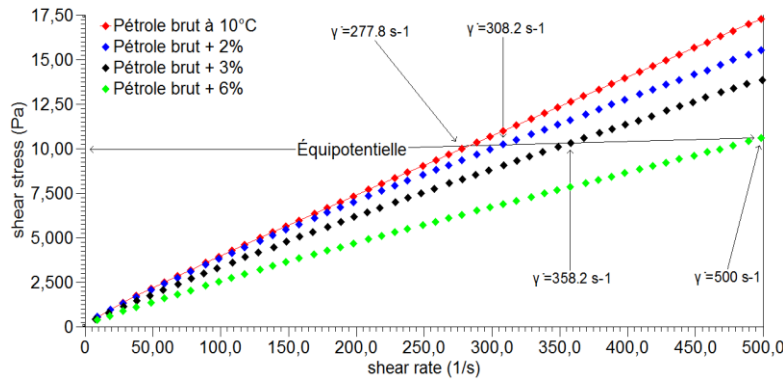


Figure. 3: Isobars points at differences concentrations of surfactant.

Table 5 also shows the variation of the flow rate for each toluene concentration. We can conclude that a reasonable addition of the toluene will cause a huge increase in the flow transported. This increase of flow transported can be up to 9.86% by addition of 2% of Toluene, about 22.44% with 3% of toluene and 44.44% with 6% of toluene, which correspond to the values of shear rate 277.8 s⁻¹, 308.2 s⁻¹, 358.2 s⁻¹ and 500 s⁻¹, respectively. Therefore, the adding of toluene to the crude oil improves the transportation capacity.

Table 5: flow rate of systems (crude oil/toluene) at different shear rate.

Concentrations (%)	Shear rate $\dot{\gamma}$ (s^{-1})	Flow rate (l/s)
0	277.8	2180.73
2	308.2	2419.37
3	358,2	2811.87
6	500	3925.00

4. CONCLUSIONS

- The study of the effect of addition of the surfactant on the rheological behavior and the transport capacity of the Algeria crude oil, showed that:
- The rheological properties of the studied crude oil were significantly influenced by the addition of some concentrations of toluene.
- The apparent viscosity of the crude oil decreases significantly with the concentration of surfactant.
- The yield stress required starting the flow decreases significantly with the addition of the surfactant; therefore, less energy will be required to start the flow.
- Increasing the concentration of the additive also has a positive effect on the flow capacity of the crude oil.
- Compared to the values of the untreated crude oil, the flow rate is increased by a factor of 44% by addition of 6% toluene. This information is very important for the transportation of crude oil.

5. References

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