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Rheological behavior of Hassi Berkine crude oil

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Abstract

The crude oil transport capacity in pipelines depends on the energy supplied from the pumping station and the energy losses that may undergo the fluid particles. The energy consumption depends on the fluid behavior law transported hence the need to conduct a rheological characterization of fluid. Crude oil is a mixture of different chemical components that may vary from one field to another or of a well at another. Crude oil characterization comes from the Hassi Berkine oil field (southern Algeria). The tests were carried out using a AR2000 rheometer of TA-Instrument. a Couette type rotation viscometer of two coaxial cylinders. Several temperatures were tested 10 °C, 15 °C and 20 °C by using a thermostated bath. For each of these temperatures, we have represents the evolution of the shear stress and viscosity versus shear rate. The results were compared with rheological models Bingham, Casson and Herschel-Bulkley. Generally the Herschel-Bulkley model corroborating best experimental results for the studied oil. We note a strong influence of rheological parameters measured with the temperature.

1. Introduction

Rheology is a science which studies the deformation and the flow of the fluids or of the solids under the influence of the constraints which theirs are applied. The rheological properties have a great importance in mechanics of the fluids. Following the impotence of the mechanics of the fluids and solids to describe the properties of the complex materials which are neither fluid nor solid was born rheology in 1928. The Parameters to be measured in rheology: the viscosity under the action of the stress as well as the elasticity for the complex fluids. The crude oil is a mixture of hydrocarbons and molecules called resins and asphaltenes also containing other atoms, mainly sulfur, nitrogen and oxygen. This composition can vary from a field with another [1] and [2]. Various studies of characterization of the crude were undertaken throughout the world. There may be mentioned: the study of Machado et al. [3] on the crude oil Brazilian, El-Gamal and Gad [4] on the paraffinic crude oil of Embarka (Egypt) without omitting those of Deshmukh and Bharambe [5] carried out on the crude of Nada (Gujarat, India) in 2008. These studies showed that the properties of the crude oil depend on its origin and its components as well as its chemical composition. In addition, the energy dissipated or stored in a system also influences to a significant degree of the rheological parameters and consequently of the quantity of transported fluid [6]. The present study fits precisely in this objective, one proposes in this article studied the rheological behavior of the crude coming from Hassi Berkine and to compare the experimental results with the rheological models. We highlight the influence of the rheological behavior and its parameters while varying the temperature. A partner of test in dynamic mode will be introduced.

2. Materials used and experiments

The specimen of crude oil was collected from the reservoir of the sector of Hassi Berkine. The rheological tests were carried out using AR-2000 rheometer from TA-Instruments with geometry Couette (diameter 14 mm). This rheometer can be operated in several modes. They were universal controlled rate (CR) mode, the controlled stress (CS) mode and the oscillation (OSC) test modes. Various geometries can be used, one can quote: plan-plan, plan-cone or that which we used in our case. We used a cylindrical geometry, Couette type, with a diameter of 14 mm and a 1 mm gap between the upper and lower plates. Due to his large surface area, we can get good accuracy with this type of device and the measurements can be obtained for very small viscosity values. The rheological parameters (the yield stress, the plastic viscosity, and the Flow index) are determined from the adjustment of flow curves using the corresponding rheological models, namely, Herschel-Bulkley, Casson, Bingham without omitting that Ostwald de Waele without constraint threshold. The protocol of test selected corresponds to that used by El Gamal [4] and Machado [3], namely: The sample is placed in the Couette system, a pre-shearing is carried out during 30 seconds with a gradient speed of 50 S^{-1}, and it to establish a uniform initial state for all the samples. The latter will be left at rest until the stabilization of the normal constraint, then the procedure of acquisition is started; the shear rate is imposed by stages which go up gradually growing between 0,01 S^{-1} and 120 S^{-1}. The following temperatures: were tested 10 ° C, 15 ° C and 20 ° C using a thermostat bath.

3. Results and analysis

3.1. Flow mode

The figures 1 and 2 respectively represent the evolution of the shear stress and viscosity according to the shear rate for various temperatures. For each temperature tested, we renewed the sample of the air-gap. The results obtained show the non-Newtonian character pseudo-plastic, i.e., there are not a flow, when the pressure applied is lower than a breaking value τ_c [7]; this latter depends on the temperature tested. We can also notice that the curves of flows present similar tendencies for all the temperatures of test. A progressive increase in the shear stress is observed with the increase in the shear rate this is in conformity with the results of Al-Zahrani et al in 1998 [8].

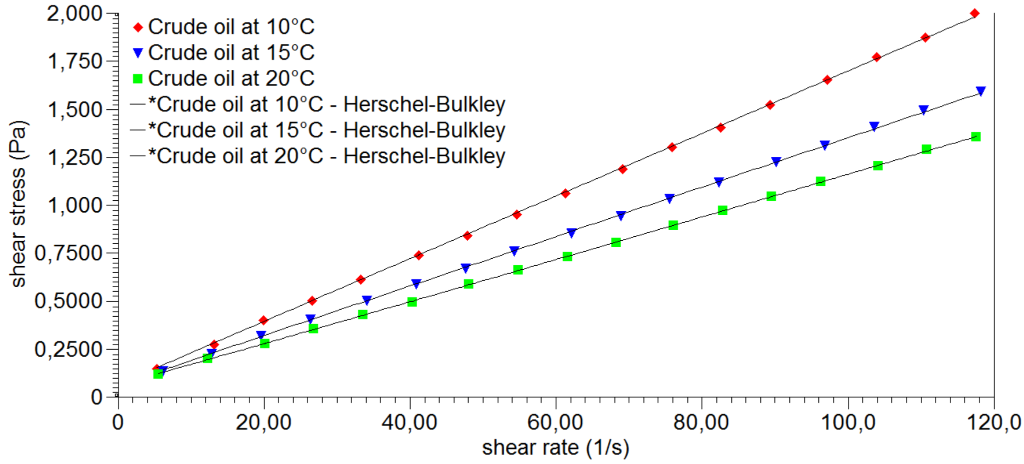

Figure 1: Evolution of the shear stress as a function of shear rate of crude oil for different temperatures.

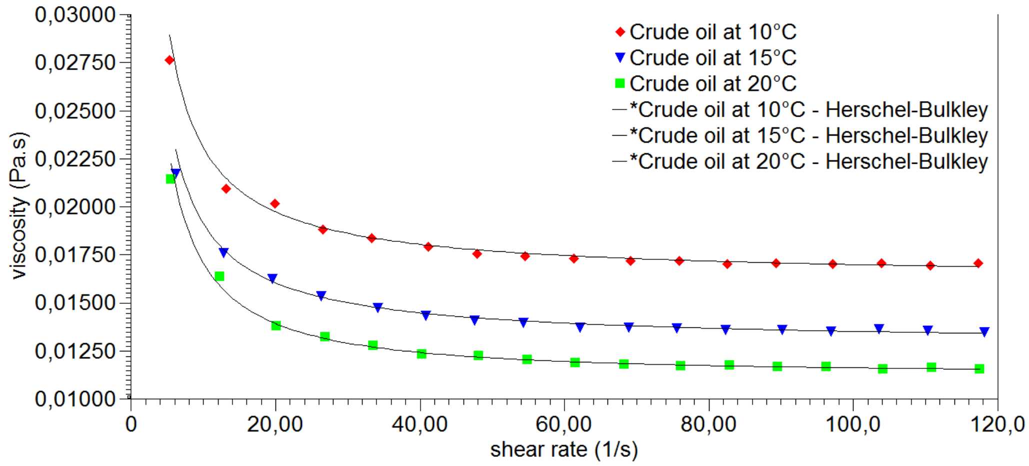

Figure 2: Evolution of the viscosity versus crude oil shear rate for different temperatures.

The flow curves and rheological parameters shown in Figure 1 and Figure 2, show that the crude oil studied obey a power law with the yield stress. It may therefore be represented by rheological models such as the Herschel-Bulkley [9], Bingham [10] or the Casson [11]. This model is three and two parameters.

Table 1: Rheological Models

Rheological Model	Equations	Parameters
Herschel-Bulkley	$\tau = \tau_c + k\dot{\gamma}^n$	τ_c, k, n
Bingham plastic	$\tau = \tau_c + \eta_B\dot{\gamma}$	τ_c, η_B
Casson	$\sqrt{\tau} = \sqrt{\tau_c} + \sqrt{\eta_c\dot{\gamma}}$	τ_c, η_c

Were:

τ_c : Yield stress

n: Flow index

k: Consistency index

η_B : Viscosity according to Bingham
η_c : Viscosity according to Casson

For each of the models mentioned above, we determine rheological parameters corresponding to each model are shown in Table 2, 3 and 4.Based on the statistical parameter of standard error. It is noted that this is the Herschel-Bulkley model that provides the best fit of the rheological data in the case of temperatures tested.

Table 2: Rheological parameters following the Herschel Bulkley model

Rheological Model	T(°C)	Standard error	Rheological Parameters		
			τ_c (Pa)	k (Pa.s)	n
Herchel-Bulkley	10	1,45 E-3	0,117	0,012	1,052
	15	7,21 E-4	0,101	0,009	1,067
	20	0,092	0,106	0,008	1,060

Table 3: Rheological parameters following the Bingham rheological model

Rheological Model	T (°C)	Standard error	Rheological Parameters	
			τ_c (Pa)	η_B (Pa.s)
Bingham	10	6,17	2,9 E-4	0,0174
	15	8,53	8,8 E-5	0,0119
	20	7,027	2,3 E-5	0.0036

Table 4: Rheological parameters following the Casson rheological model

Rheological Model	T (°C)	Standard error	Rheological Parameters	
			τ_c (Pa)	η_C (Pa.s)
Casson	10	6,264	1,4 E-6	0,0174
	15	11,03	9,5 E-4	0,0138
	20	7.113	9,4 E-7	0,0119

3.2. Oscillatory mode

The tests were conducted on the crude oil with other samples for the same temperatures in oscillatory mode, which allowed us to measure the loss and storage modules by varying the frequency. These results are shown in Figure 3. The range of frequencies used is 0.01 rad/s to 12 rad/s.

Figure 3, shows a gradual increase in G 'and G' 'with the frequency. He explains that the crude oil has a response from the linear relationship on the frequency range examined at different temperatures. This curve clearly shows the great influence of temperature on the viscous modulus G " in conformity with the results of [12], [13] and [14].

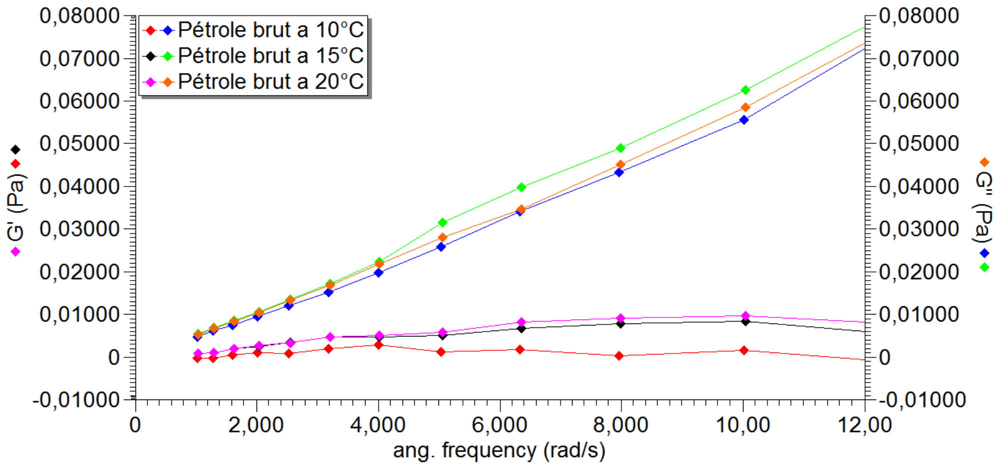

Figure 3: Evolution of loss modulus and storage of crude oil at different temperatures.

These results shown in Figure 3, clearly shows that the elastic modulus G 'increases with increasing temperature. The measurement results show that the viscosity modulus G " reaches higher values than the values of the elastic modulus G 'at different temperatures along the frequency being tested. This means that the energy stored in the crude oil is less than the energy dissipated as heat. It is also clear that the temperature has less effect on the elastic modulus G 'and the elasticity is much more dependent on the frequency. At 15 ° C, the crude oil viscosity modulus increases significantly compared to that of 20 ° C as can be seen in Figure 3. However, this module takes less value for a temperature of 10 ° C.

Conclusion

- The crude oil studied behaves as a rheofluidifiant fluid with yield stress and follows the rheological model of Herschel-Bulkley;
- The temperature significantly affects the evolution of the flow curves; the increase causes a decrease in the apparent viscosity of the crude oil and the reduction of yield stress;
- For low values of shear rate, the viscosity decreases and as the increase of the shear rate;
- Crude oil dynamic tests showed that G " depends on the temperature and frequency, the elastic modulus G' decreased with increasing temperature;
- Dynamic analysis showed that the studied raw behaves like a viscous fluid rather than a resilient fluid.

References

[1] Li H, Zhang J. A generalized model for predicting non-Newtonian viscosity of waxy crudes as a function of temperature and precipitated wax☆. Fuel. 2003;82:1387-97.

[2] Dante RC, Geffroy E, Chávez A. Viscoelastic models for Mexican heavy crude oil and comparison with a mixture of heptadecane and eicosane. Part II. Fuel. 2007;86:2403-9.

[3] Machado AL, Lucas EF, González G. Poly (ethylene-co-vinyl acetate)(EVA) as wax inhibitor of a Brazilian crude oil: oil viscosity, pour point and phase behavior of organic solutions. Journal of Petroleum Science and Engineering. 2001;32:159-65.

[4] El-Gamal I, Gad E. Low temperature rheological behavior of Umbarka waxy crude and influence of flow improver. Oil & Gas Science and Technology. 1997;52:369-79.

[5]Deshmukh, S, Bharambe, D. P. Synthesis of polymeric pour depressants for Nad crude oil (Gujarat, India) and its impact on oil rheology. Fuel Processing Technology. 2008 ; 89 :227-233.

[6] Jorge Antonio Avendaño Benavides. Viscoélasticité et récupération améliorée du pétrole. Ph.D. thesis,Sciences, Ingénierie Environnement: PARIS-EST; 2012.

[7] Hasan SW, Ghannam MT, Esmail N. Heavy crude oil viscosity reduction and rheology for pipeline transportation. Fuel. 2010;89:1095-100.

[8] Al-Zahrani SM, Al-Fariss TF. A general model for the viscosity of waxy oils. Chemical Engineering and Processing: Process Intensification. 1998;37:433-7.

[9] Herschel, W.H., and R. Bulkley, Kolloid Z. 39(1926) 290.

[10] Bingham, E.C., Fluidity and plasticity McGraw-Hill, 1922.

[11] N.Casson, Proceedings of the Conference of the B.S.R.(1957) 102.

[12] Ghannam MT, Hasan SW, Abu-Jdayil B, Esmail N. Rheological properties of heavy & light crude oil mixtures for improving flowability. Journal of Petroleum Science and Engineering. 2012;81:122-8.

[13] Lin Y, Han X, Huang J, Fu H, Yu C. A facile route to design pH-responsive viscoelastic wormlike micelles: Smart use of hydrotropes. Journal of Colloid and Interface Science. 2009;330:449-55.

[14] Torres LG, Iturbe R, Snowden MJ, Chowdhry BZ, Leharne SA. Preparation of o/w emulsions stabilized by solid particles and their characterization by oscillatory rheology. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 2007;302:439-48.