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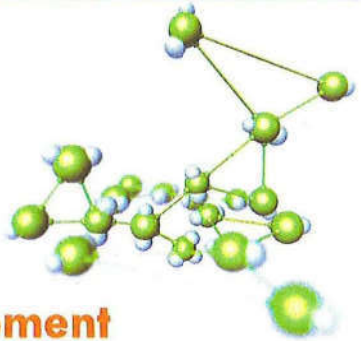

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Rheological behavior Study of Hassi Messaoud crude oil.

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Abstract — In the present study, we investigated the crude oil's rheological behavior which comes from Hassi Messaoud region. This study discusses the effect of shear rate, and temperature on the viscosity and the yield stress. The rheological characterization was performed at different temperatures (5°C, 10°C, 15°C, 20°C and 50°C) by using the rheometer AR 2000 TA-Instruments. The results indicated that the rheological properties were significantly influenced by the temperature variation. It is also noted that the crude oil behaved as non-Newtonian fluids at low shear rate, whereas the Newtonian behavior occurs at high values of shear rate over ITS wide range. In order to evaluate the stored energy and the energy dissipate during the flow in the crude oil, the elastic modulus, (G'), and the loss modulus, (G"), were determined. The results also indicated that the crude oil's viscoelasticity characters are significantly temperature-dependent.

Keywords*:* Crude oil, rheological behaviors, viscosity, yields stress, viscoelasticity character.

I.Introduction

It is very necessary to know the oil's rheological properties, for all the transfer processes of fluids from one location to another. Indeed, the rheological properties are considered as one of the main parameters which governing the transportation of crude oil in good conditions [1]. The pipeline's use is the most convenient and economical way for the crude oil transportation [2, 3, 4]. Indeed, in the petroleum industry, the crude oil's viscosity has an important role in the calculations of fluid flow through reservoir rock and the pressure loss and the design of surface facilities. The bibliographic research informs us that crude oil properties depend of its type and origin, as well as of the nature of its chemical composition [1, 5, 6]. For this aim, the effect of several parameters such as the shear rate and the temperature of crude oil on rheological parameters were determined. The results obtained showed that the viscosity of crude oil decreases with the increase of the temperature and the yield stress is reduced. The rheological behavior of crude oils is a Newtonian behavior over a wide range of the shear rates, for the high values of shear rate, while it has a non-Newtonian behavior for the low values of shear rate (the crude oil has a Newtonian behavior over a wide range of the shear rates , for the high values , whereas a non- Newtonian behavior for the low values) [1, 7, 8], the model Herschel Bulkley was found to describe correctly this behavior, also the research would provide quantitative information about the effect of temperature on the viscoelastic characters [1, 9].

II. Experimental Method

II.1 *Oil Samples*

The crude oil from the transportation national and marketing of hydrocarbons company (Sonatrach), Hassi Messaoud, Algeria, was employed throughout this study. The physical properties of the crude oil are measured and can be summarized as follows: specific gravity is 0.87; asphaltene is 2.5% by weight. Five temperatures 5°C, 10°C, 15°C, 20°C and 50°C were selected since the crude oil in this region is subjected to these extreme temperatures. The crude oil was homogenized by shaking it in an incubator shaker model Heidolph MR 3001k at 100 rpm at 20°C for 5 min.

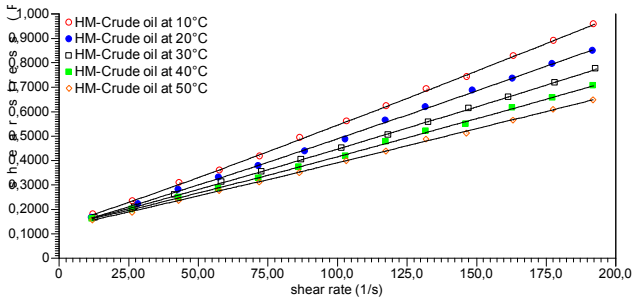
II.1.1Protocol Set-up and Measurements

For all rheological measurements, (rheological properties and study in oscillation mode) were carried out using AR-2000 rheometer with geometry Couette (diameter 14 mm). Initially, the sample will be subjected to a shear rate of 1000 s^{-1} to erase its memory [10]. All the samples will be subjected to a pre-shear for 60 seconds with a shear rate of 0.15 s^{-1}, for a correct homogenization of the sample [11,12]. The samples are then left to settle for 1 min before the acquisition procedure of data is started. The range of the shear rate applied varied from 0.01 s^{-1} to 700 s^{-1}. The dynamic tests (in oscillation mode) were conducted in the linear viscoelasticity domain for the frequency range of 1 to 60 rad/s.

III. Results and discussions

The flow behavior of crude oil was studied over wide range of shear rate over a range of temperature 10°C-50°C. Figure 1 shows the rheogram in terms of shear stress and shear rate at different temperature.

Figure 1: Flow curves of the HM- Algeria crude oil at



different test temperatures;

The flow curves show that the shear stress increases gradually with shear rate,It can be observed that the flow curves present similar trends for all the temperatures test, Also, the curves show clearly the Non-Newtonian pseudo-plastic character of the crude oil for temperatures chosen (Figure 1).

III.1 Yield Stress Measurements

The yield stress is a limit stress, below which the sample behaves as a solid. Under this value, the elastic deformation disappears. The relation-ship between the elastic deformation and the applied stress is linear. However, above the values of the yield stress, the application of stress leads to an unlimited deformation to cause the fluid to flow [9, 13].

TABLE 2: THE EXPERIMENTAL RESULTS OF YIELD STRESS AT DIFFERENT TEMPERATURES.

	Temperature	Yield Stress
HM-Crude oil	10°C	0,1794
	20°C	0,1656
	30°C	0,1646
	40°C	0,1615
	50°C	0,1578

An analysis based on the Herschel-Bulkley model was used to determine the yield stress of crude oil at different temperatures. It was observed that the yield stress was required to

start the flow decreasing with increase in temperature which makes the start of flow easier. It should be noted that a little reduction in the yield stress was observed for each temperature tested. In general, the yield stress of the Algeria crude oil reduces to 12.04% when the temperature varies from 10°C to 50°C.

III.2 *Effect of shear rate on viscosity at different temperature*

The effect of shear rate on viscosity at different temperatures was studied and depicted in Figure 2. From the viscosity investigation versus different temperatures, it is observed that there are a few viscosity reductions over the temperatures tests. This can be attributed to less effect of the temperature on the viscosity and chemical structure of the crude oil's components. As shown in Figure 2 at lower shear rates, viscosity is higher which becomes constant with the increase of shear rate. This is due to the permanent dissipation of heavier components at high shear rate.

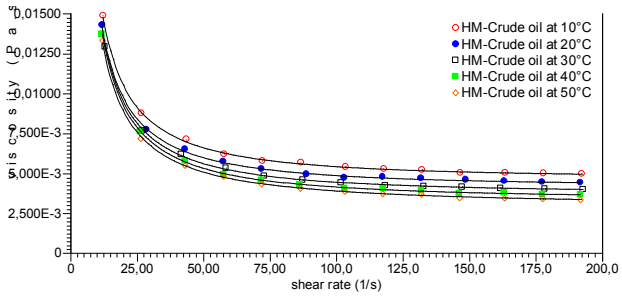


Figure 2: Flow viscosity of the HM- Algeria crude oil at different test temperatures;

III.3 *Effect of temperature on the Shear stress*

The shear stress is assimilated to an injection pressure or a flow of crude oil in the pipe. Therefore It is too important to predict the effect of the temperature; because in order to reduce the pumping pressure and, hence, the costs in the petroleum pipeline transportation. The variation of the shear stress of the crude oil with different temperatures is shown in Table 3.

TABLE 3–SHEAR STRESS (PA) OF CRUDE OIL AT A SHEAR RATE OF 146.2 S^{-1}.

	Temperature	*Shear stress*
HM-Crude oil	10°C	0,7409
	20°C	0,6855
	30°C	0,6136
	40°C	0,5495
	50°C	0,5126

From the Table 3, it was observed that there is a considerable decrease in the shear stress (from 0,7409 Pa at 10°C to 0,5126 Pa at 50°C),this may be due to Increase in temperature leads to reduction in the viscosity of the high weight components of synthetic crude oil i.e. waxes and asphaltenes.

III.3 *Viscoelastic behavior of HM-crude oil: (Study in dynamic mode)*

The dynamic test is an important tool of the rheological investigation to study the viscoelastic behavior of the crude oil [14]. For this raison, two parameters were measured: the elastic modulus G' and the viscous modulus G''. The term of elastic modulus (G') indicates the ability of the material to store energy, while the term viscous modulus (G'') indicates the ability of the material to dissipate energy which has been used to initiate the flow.

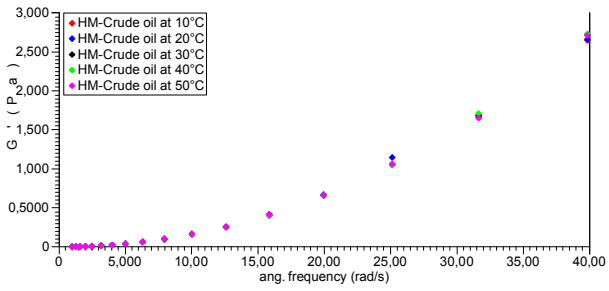


Figure 3: Viscous modulus of HM-Algeria crude oil at different test temperatures.

The viscous modulus and the elastic module versus ang-frequency for the crude oil at different temperatures are plotted in the figure 3 and 4. The figure 3 indicates that, by the increases of the temperature there is no change in the elastic modulus. It should be note however, that these results depend more on the frequency.

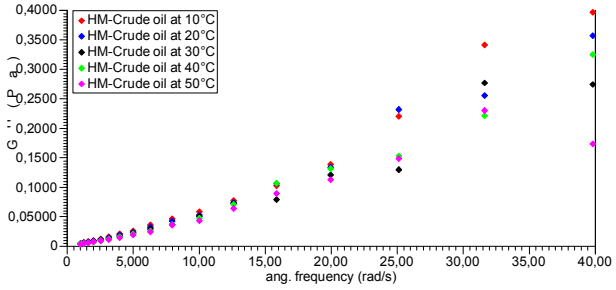


Figure 4: Elastic modulus of HM-Algeria crude oil at different test temperatures;

A close examination of figure 4 shows that the viscous modulus G" was always higher than the elastic modulus G' within the experimental frequency used and it was dependent on the frequency. This means that the energy stored in the crude oil is less than the energy dissipated as heat. This curve illustrates clearly the great influence of the temperature on the viscous modulus G'' [14,15,16].The viscous modulus of the crude oil decrease significantly by the increases of the temperature. Therefore, the crude oil tends to behave in a viscous liquid behavior.

I.V Conclusion

The current study is carried out to investigate the rheological properties of Hassi M'essouad (OMM-413) crude oil. The following conclusions can be made:

The crude oil exhibits a non-Newtonian shear thinning behavior over the examined range of shear rates; the viscosity of the crude oil

decreases slowly with temperature over the range of 10–50 °C; the yield stress of the crude oil decreases slowly with temperature. It reaches to 0.17 Pa at 10 °C and it decreases to 0.15 Pa at 50 °C; The dynamic test of crude oil showed that G' depends only on the frequency; the viscous modulus of the heavy crude oil decreases significantly with temperature; the crude oil behaves in a viscous liquid behavior more than as a solid-like material.

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