RHEOLOGICAL CHARACTERISATION OF CRUDE OIL FOR DRILLING AND PRODUCTION PETROLEUM APPLICATION

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ABSTRACT

Crude oil is subjected to important variation in temperature during its extraction and transport in the pipelines, or when used in oil based drilling fluids. These changes have a direct effect on the rheology of oil which conditions its transport or ensures a good cleaning of the well as a drilling mud. According to these considerations, it is interesting to know how the rheological properties of crude oil vary as a function of temperature over a relatively long period of time. This study has been conducted on a sample of crude oil, which has been subsequently aged several months, the rheological behavior of oil was determined at a temperature of 20 ° C by using a Rheometer ARES, then the viscosity temperature relationship was investigated for temperatures of 20 °, 30 °, 40 °, 50 ° 60 ° and 80 ° C, and finally the activation energies of the two samples were calculated

KEY WORDS: crude oil; rheology; viscosity; aging, activation energy.

RESUME

Le pétrole brut est sujet à d'importantes variations de la température durant son extraction et son transport dans les pipelines, ou pendant son utilisation dans les fluides de forage à base d'huile. Ces changements ont un effet direct sur la rhéologie de l'huile qui conditionne le transport et assure un bon nettoyage du puits lorsqu'il est utilisé dans les compositions des boues de forage. En tenant compte de ces considérations, il est intéressant de connaître comment varient les propriétés rhéologiques du pétrole brut en fonction de la température sur une période relativement élevée. Cette étude a été faite sur un échantillon de pétrole brut qui a été vieilli de quelques mois, le comportement rhéologique du pétrole a été déterminé à la température de 20 °C en utilisant le rhéomètre ARES , ensuite la relation viscosité- température a été étudiée pour les températures de 20 °, 30 °, 40 °, 50 ° 60 ° et 80 ° C , finalement les énergies d'activation des deux échantillons ont été calculées.

1 INTRODUCTION

Crude oil can be divided into two main classes: light and heavy. Density is an important characteristic of crude oil, it determines its classification: whether it is light or heavy. Principally, the chemical composition of all crude oil is hydrocarbons. Although hundreds of the different crude oils are produced and transported each year in the world, the composition (natural) chemical of each one is generally well known [4]. However a wide variation in properties is found from the lightest crude oils to the highly asphaltenic crude.

Crude oil has different applications in petroleum industry, in some cases; crude oil is added in oil-based muds. In addition to diesel oil, weathered crude oils and various refined oils have been used as the oil phase for oil-based muds [3].

The light crude oil has a good flowability due to its low viscosity which changes with temperature. Indeed the temperature of crude oil varies widely along the flow from the reservoir to production platform; this has a direct effect on the rheology of crude oil which is very important. Rheological properties of crude oil are fundamental for crude oil pipeline design and operation [12]. Therefore, the knowledge of rheological parameters, such as viscosity, shear rate and shear stress of crude oil are very important in the petroleum field. Other application, light oils are less efficient in reducing the viscosity of heavy oils than condensates [11]

In this study, the same sample of crude oil was studied at different period. Indeed, the process of aging materials is an interesting subject for scholars. The variation of rheological properties of oil over time is an important area in the petroleum industry, it can be applied for the recycling of oil based muds or the study of oil stagnation in general.

Viscosity-temperature relation of crude oil had been determined by experiments. Rheological characteristics of crude oil were measured with a Rheometric Scientific ARES at temperatures of 20°, 30°, 40°, 50°, 60° and 80°C. The results showed that crude oil exhibits a Newtonian behavior.A kinetic model (Arrhenius) was used to determine the activation energies of the samples studied. Thermal analysis characterizes well fossil fuel research area；in recent years the application of thermal analysis to study the combustion behavior of crude oils has gained a wide acceptance among researchers [6]

2 EXPERIMENTAL

2.1 Crude Oil And Characteristic.

The same sample of crude oil was studied at different period; sample 1 represents crude oil while sample 2 has been aged for some months. These oils are very fluid, they have a dark color, a strong smell and they evaporate quickly. During the experiment, low variation was observed for temperatures of 50, 60°C.

The API gravity of the sample was calculated by using the equation 1 [1]:

$$API = \frac{141.5}{S.G} - 131.5 \quad (1)$$

Where S.G is the specific gravity of the sample equal to 0.785 kg/l. API gravity calculated is 48.5, then the oil used in this study was light crude oil

2.2 Materials.Mcscss

All rheological measurements were performed on a Rheometric Scientific ARES controlled strain rheometer with Couette with grooved cylinder. Coaxial cylinders have the following characteristics: outside diameter= 34 mm, inside diameter = 32 mm and length = 33.34 mm. The range of the shear rate varies from 5 to 300 s-1 and the temperature was regulated using a thermostatic bath

3 RESULTS AND DISCUSSION

3.1 Rheological Behavior of crude oil

In this experiment, the relationship between viscosity/shear rates was studied at 20°C.The range of shear rate varied from 5 to 300 s^{-1}. As shown in figure 1, the samples of crude oil are Newtonian fluids. Their flow curves $\eta=f(\dot{\gamma})$, at a constant temperature, are linear. This means, the viscosity is constant according the shear rate in the fluid. Eq. (2) shows the relation used to characterize these fluids:

$$\eta = \frac{\tau}{\dot{\gamma}} \quad (2)$$

Figure 1 shows that the viscosity of oil decreases over time, it can be seen from this result that weathering has a significant effect on the crude oil.

η : viscosity

τ : shear stress

$\dot{\gamma}$: shear rate

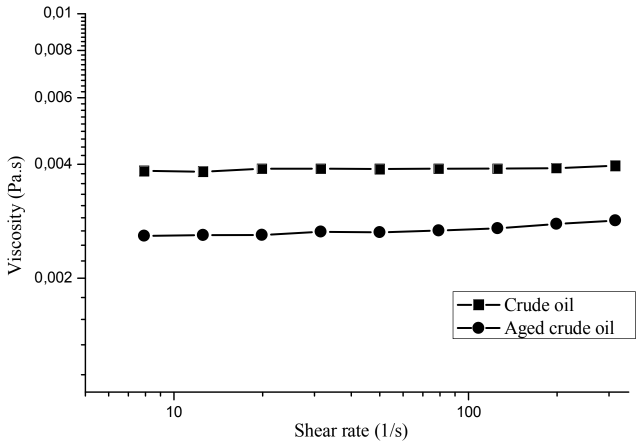

Figure 1: Comparison between two crude oil samples at 20°C

3.2 Effect of shear rate and temperature on viscosity for both samples

In this experiment, we varied temperatures of 20°, 30°, 40°, 60° and 80°C of both samples. Figs.2 and 3 show the viscosity variation with the shear rates under different temperatures, and the values of the calculated parameters listed in Table 1, one can notice the difference between the viscosities when changing the temperature. The results demonstrated that each sample shows different values of viscosities at low and high temperatures. The thermal stability of the light crude oils is satisfactory; this confirms that the crude oil sample was stored under proper conditions

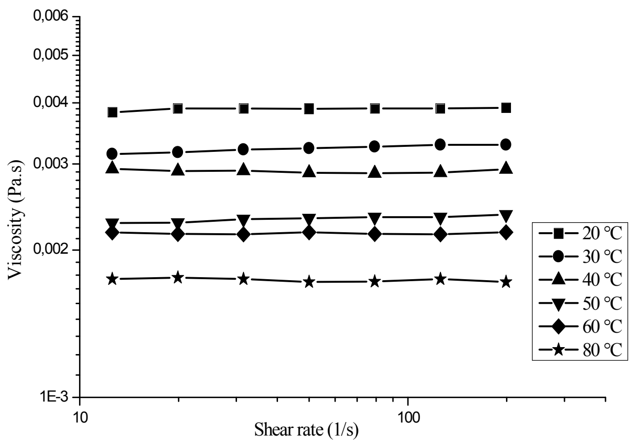

Figure 2: Crude oil viscosities at different temperatures as function of shear rate

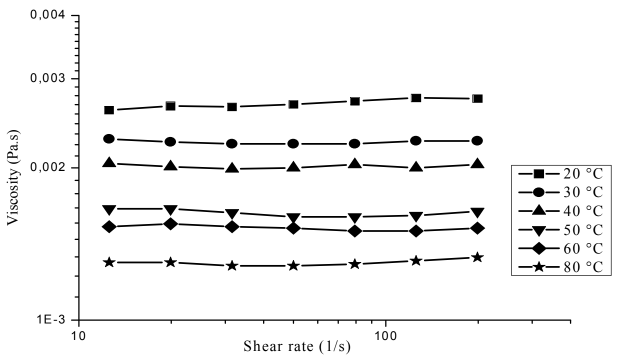

Figure 3: aged crude oil viscosities at different temperatures as function of shear rate

From the Figures 2 and 3 , the results demonstrate that the extreme curves i.e. at the temperature of 20° and 80°C are specific (apparent),while the curves for 30 °, 40 ° C and 50 °, 60 ° C are similar. These results suggest that a difference of 10°C does not have a significant influence on the viscosity of the light crude oil that is resistant to temperature variation. In addition, the variation is quite visible between 60° and 80°C for a step of 20°C. The same remark is observed for sample 2 (aged crude oil) of figure 3 but with the curves closer together. In Table 1, the results show that viscosity decreases with increases in temperature. Indeed the range of viscosities at equal temperatures has decreased compared to Sample 1 (crude oil)

Table 1: Values of viscosities according the temperatures of crude oil

Temperature (°C)	Viscosity (Pa.s)	
	Crude oil	Aged crude oil
20	0.0039	0.0027
30	0.0032	0.0022
40	0.0029	0.0020
50	0.0023	0.0016
60	0.0021	0.0015
80	0.0017	0.0013

These results show that oil tested is stable long-term. At 80 °C , the variation is very is low indeed, in application to drilling fluids, Oil based muds are designed to be stable over long periods of time even when exposed to high temperatures. Another choice to dilute heavy oils is to use a light crude, with an API gravity range from 35 to 42 [5, 10]

The viscosity of real materials can be significantly affected by such variables as temperature and pressure, and it is clearly important for drilling fluid engineers to understand the way viscosity depends on such variables [2]

For all liquids, viscosity decreases with increasing temperature and decreasing pressure. The strong temperature dependence of viscosity is such that, to produce accurate results, great care has to be taken with temperature control in viscometer. For liquids of higher viscosity, given their stronger viscosity dependence on temperature, even greater care has to be taken [2]

3.3 Activation Energy

A Newtonian behavior is obtained for the model crude oil, characterized with viscosity increase according temperature. The data were fitted to an Arrhenius equation which is expressed in a simple exponential form as following Eq (3) [8]:

$$\mu = A \times exp\left(\frac{Ea}{RT}\right) \tag{3}$$

where µ is the Newtonian dynamic viscosity , A is a constant dependent on the entropy of activation of flow, E_a is the activation energy of viscous flow , R is the universal gas constant and T is the absolute temperature.

As shown in figure 4, kinetic parameters of the samples were determined using Arrhenius equation and the results are discussed. The classical Arrhenius model was applied, and the activation energy for the crude oil was calculated.

The results showed that the Arrhenius model fitted the data well in the entire range of temperatures with coefficients of correlation of 96 and 99%

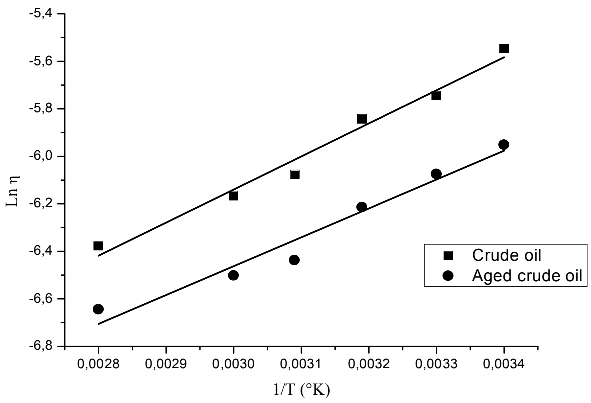

Figure 4: Activation energy calculation by Arhenius method

The experimental activation energy for Sample 1 was 13.92 kJ mol^{-1}, and for the sample 2, it was 102.15 kJ mol^{-1}

The activation energies do not varied much over time and their values are low, this is due to their density. It is observed that activation energy values increased as the API gravity of the crude oil decreased [6]

A classification system of the changes in composition of the aromatic fraction, based on the kinetics of ageing was proposed [9, 7].

The differences between the activation energy values of two samples can be explained with the changes of molecular structures in crude oil after a long period. Under certain conditions, in the absence of air, crude oil preserves well its properties

4 CONCLUSION.

The ageing of crude oil helps to understand certain phenomena, in the absence of air; crude oil preserved well rheological properties

The increase in temperature implies a reduction in viscosity in the crude oil samples which exhibit a Newtonian behavior. The activation energy values of the samples were determined by using Arrhenius methods and calculation results show that activation energy will decrease after a long period of conservation.

Well preserved, safe from the air and only exposed to the variations of the seasonal temperatures, the rheological and kinetic properties vary little in time. The use of the crude in drilling muds which are exposed to high temperatures in the depths of the ground shows that oil is relatively stable and its viscosity varies slightly in the range of the tested temperatures This study can be integrated with other works, concerning the use of oil based drilling fluids or in order to simulate the evolution of crude oil.

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