Journal of Petroleum Science and Engineering 133 (2015) 184–191

Contents lists available at ScienceDirect

Journal of Petroleum Science and Engineering

journal homepage: www.elsevier.com/locate/petrol

Rheological behavior of an Algerian crude oil containing Sodium Dodecyl Benzene Sulfonate (SDBS) as a surfactant: Flow test and study in dynamic mode

Djamal Eddine Djemiat [a], Abdelhamid Safri [a], Abdelbaki Benmounah [b], Brahim Safi [b,*]

[a] Laboratory of Environment, Geotechnics and Hydraulics (LEG-HYD)/University of Science and Technology – Houari Boumediene (USTHB), Algeria
[b] Research Unit, Materials, Processes and Environment (UR-MPE), Boumerdes University, Algeria

ARTICLE INFO

Article history:
Received 21 January 2015
Received in revised form
5 May 2015
Accepted 14 May 2015
Available online 4 June 2015

Keywords:
Crude oil
Temperature
Additive
Rheological behaviors
Viscosity
Yield stress
Viscoelasticity character

ABSTRACT

In order to improve the flow characteristics, this work aims to study the rheological behavior of the oil crude (coming from the oil field of Tin Fouye Tabankort/South Algeria) with and without additive friction reducing. An experimental study was performed by measuring the rheological characteristics by flow tests and dynamic mode (oscillation) at different temperatures (20 °C, 30 °C and 50 °C) using the rheometer AR2000. The temperature of the crude oil varies between these extreme values in the south of Algeria. For this, the effect of the shear rate, the temperature and the additive concentration of Sodium Dodecyl Benzene Sulfonate (SDBS) on the rheological parameters have been studied. The obtained results show that the crude oil exhibits a non-Newtonian behavior at a low shear rate which can be described by the Herschel–Bulkley model. It was also noted that the Newtonian behavior occurs at high values of the gradient of shear rate. The viscoelasticity character of the crude oil by identifying of the elastic modulus (G′) and the viscous modulus (G″), has indicated that the rheological properties of crude oil were significantly influenced by the additive.

1. Introduction

According to the assumption of a global economic growth of 3.9% per year, the global oil production demand is now projected to increase by roughly 1.2% per year over the next five years (equivalent to 1.1 mb/d); that is an increase from 89.0 mb/d in 2011 to 95.7 mb/d in 2017 (Report of International Energy Agency (IEA), 2012). To meet this need, the pipeline transportation is considered as the most efficient and economical mean to transport the crude oil and its different products (Saniere et al., 2004; Abdurahman et al., 2012; Thuc et al., 2006). However, the rheological properties for petroleum oils are very necessary for all the transfer processes of fluids from one location to another. Indeed, the rheological properties are considered as one of the main parameters governing the transportation of crude oil or petroleum oils in good conditions. For this aim, oil companies often plan to optimally exploit existing networks whilst avoiding engineering problems. It has been proven that the rheological parameters affect significantly the ability of transportation of crude oil in pipelines. Several studies were conducted to discover useful techniques in order to reduce the pressure drop and viscosity of the crude oil respectively for the pipeline transport and other applications (heating, dilution, oil-in-water systems, core annular flow and partial up-grading), in order to improve the flow properties of crude oils (Saniere et al., 2004; Iona, 1978; Mansour et al., 1988). One technique habitually used consists of adding chemical agents named (DRA). In this sense, the addition of surfactant or polymer responds to this aims (Machado et al., 2001; Al-Roomi et al., 2004; El-Gamal and Gad, 1997; Mowla and Naderi, 2006). Few results have been published concerning the use of this additives type despite their advantages and their rather important lifespan regeneration (Bewersdorff and Ohlendorf, 1988). For this reason, a surfactant selected as a Drag Reduction Agent (DRA) is used because of its good efficiency to improve the flow characteristics of crude oil and reduce pressure drops (Rassoul and Hadi, 2007; Abdul-Hakeem, 2000).

More recent studies have been carried out on the effect of surfactants on rheological properties of crude oil or synthetic crude oil. These studies have shown the need to use additives to improve key rheological parameters that are responsible for the flow of crude oil. Indeed, the rheological properties of crude oil are highly influenced by several significant parameters such as crude oil nature (dispersed phase content), surfactant (nature or

* Correspondence to: Research Unit, Materials, Processes and Environment (UR/MPE), Boumerdes University, Faculty of Engineering Sciences/Boumerdes University, Frantz fanon city, Boumerdes 35000, Algeria. Fax: +213 249 138 66.
E-mail address: safi_b73@umbb.dz (B. Safi).

http://dx.doi.org/10.1016/j.petrol.2015.05.012
0920-4105/

concentration), temperature, average droplet size, etc. (Ravindra et al., 2014; Alomair et al., 2014; Sadeghi et al., 2013; Hasan et al., 2010). The effect of several parameters such as the shear rate, the temperature and the mineral addition of crude oil on rheological parameters had been studied by (Ravindra et al., 2014). The results obtained by these authors have showed that the viscosity of crude oil decreases with an increase of the temperature and the yield stress is reduced (Chanda et al., 1998). Another study has been realized by (Sadeghi et al., 2013) on rheological properties of crude oil containing a lipophilic surfactant. These authors have found that the rheological parameters were significantly influenced by the surfactant concentration and the temperature (Sadeghi et al., 2013). 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 (Bird et al., 1960); the model Herschel Bulkley was found to describe correctly this behavior (Meriem-Benziane et al., 2008). However, it has been found that (El-Gamal and Gad, 1997; Avendaño Benavides, 2012; Livescu, 2012; Dante et al., 2006), both the Casson Model and the Bingham model fitted well with the experimental data and hence are more suitable. Indeed, It was noted that the viscosity, the elastic modulus, (G′) and the viscous modulus, (G″) were significantly changed with the increase in the surfactant concentration.

According to this bibliographic study, the crude oil properties depend on its type and origin, as well as on the nature of its chemical composition. On the other hand, the energy dissipated or stored in a system also influences significantly the rheological parameters and consequently the quantity of fluid transported will be affected. The present work aims to study the rheological characteristics of Algerian crude oil with and without of the Sodium Dodecyl Benzene Sulfonate (SDBS) as a surfactant. This surfactant has been already used by Rassoul and Hadi, (2007) as a friction reducer (to reduce losses) in oil transport pipe. In the present investigation the study is concentrated on the effect of surfactant friction reducer on rheological parameters and on the viscoelastic character of Algerian crude oil by a study dynamic mode.

2. Experimental program

2.1. Materials used and sample preparations

The crude oil specimens were collected from a reservoir of the TFT sector (Tin Fouye Tabankort/South Algeria). The physico-chemical characteristics of the crude oil used are given in Table 1. An additive is used as a surfactant in the studied crude oil. The compound Sodium Dodecyl Benzene Sulfonat (SDBS) was selected in this work. This additive is chosen for its good effectiveness in improving the flow characteristics (Rassoul and Hadi, 2007; Abdul-Hakeem, 2000). Indeed, this surfactant is soluble in the crude oil and is taken in weight part per million (wppm).

In order to prepare the studied samples, the crude oil was mixed with different concentrations of surfactant in order to prepare samples of 50 ml. For each given surfactant concentration, the sample was subjected to a given temperature (Fresh samples were used for different temperatures). Three temperatures 20 °C, 30 °C and 50 °C were selected since the crude oil in this region is subjected to these extreme temperatures. In effect, the temperature at the outlet of the separator reaches 50 °C and is nearly 20 °C at the main collection center. In addition, an intermediate temperature of 30 °C is also considered in this research. The additive concentrations used are 10, 50, 150 and 300 wppm. The crude oil was homogenized by shaking it in an incubator shaker model Heidolph MR 3001k at 250 rpm at 50 °C for 15 min.

Table 1
Sample characteristics of the crude oil used in this study.

Sample characteristics	
Gravity (°API)	32.7
Liquid density (26 °C)	0.847
TVR (g/cm^2) (35.5°)	339
BSW (%)	0.05

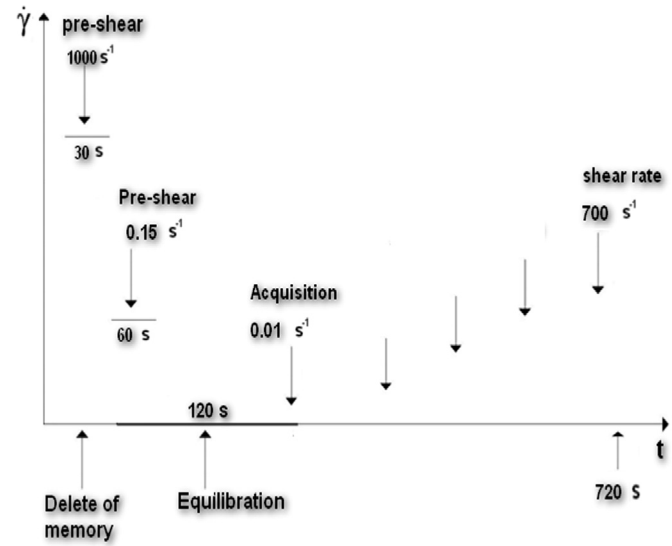

Fig. 1. Testing protocol used in this study.

2.2. Test methods and protocol

2.2.1. Rheological measurements

All rheological tests (rheological properties and study in oscillation mode) were carried out using AR-2000 rheometer with geometry Couette (diameter 14 mm). This rheometer can be operated in several modes; the universal controlled rate (CR) mode, the controlled stress (CS) mode and the oscillation (OSC) test modes. The analyses were conducted by using cylindrical and Couette geometry with a diameter of 14 mm and 1 mm gap between the upper and lower plates. Due to its large surface area, a good accuracy can be obtained with this type of device and the measurements can be carried out for very small viscosity values.

2.2.2. Testing protocol

For all rheological measurements, the test protocol given in fig. 1 has been chosen and applied for all the studied mixtures. Initially, the sample will be subjected to a shear rate of 1000 s^{-1} to erase its memory (Taraneh et al., 2008). All the samples will be subjected to a pre-shear for 60 s with a shear rate of 0.15 s^{-1}, for a correct homogenization of the sample (Al-Roomi et al., 2004; Li and Zhang, 2003). 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 1–10 rad/s. It should also be pointed out that the final results represent the average of three repeated tests on each mixture, in order to check the repeatability of the experimental data.