Experimental Study of Light Crude Oil-Water Emulsions

M. Meriem-Benziane, Sabah A. Abdul-Wahab, H. Zahloul and M. Belhadri

Abstract—This paper made an attempt to investigate the problem associated with enhancement of emulsions of light crude oil-water recovery in an oil field of Algerian Sahara. Measurements were taken through experiments using RheoStress (RS600). Factors such as shear rate, temperature and light oil concentration on the viscosity behavior were considered. Experimental measurements were performed in terms of shear stress–shear rate, yield stress and flow index on mixture of light crude oil–water. The rheological behavior of emulsion showed Non-Newtonian shear thinning behavior (Herschel-Bulkley).

The experiments done in the laboratory showed the stability of some water in light crude oil emulsions form during consolidate oil recovery process. To break the emulsion using additives may involve higher cost and could be very expensive. Therefore, further research should be directed to find solution of these problems that have been encountered.

Keywords—Emulsion, Flow index, Herschel-Bulkley model, Newton model, Oil field, Rheology, Yield stress

I. INTRODUCTION

RHEOLOGY emulsions study is important in many industrial applications such as paints, agrochemicals, pharmaceuticals, bitumen emulsions.

In petroleum industry emulsions formation is a big problem. Crude oil when comes from oil fields often mix with water. As this oil–water mixture passes over mechanical input, it leads to the formation of water-in-oil (W/O) emulsions [1]. Emulsion properties like stability and rheological properties are governed by many variables such as temperature and chemical composition [1], [2].

The rheology and stability of oil-in-water emulsions depend upon interaction between droplets. The rheological behavior of an emulsion may be either Newtonian or non-Newtonian depending upon its chemical composition [2], [3].

According to E. Dickinson [4], the rheological behavior of heavy oil-water emulsion is non-Newtonian. During the transport of oil via pipeline, the stability of crude oil is particularly favored by the concentration of chemical additives such as surfactants which contribute to decrease the interfacial tension between the crude oil and the water [5].

The water content in the oil emulsions can be high. But, this quantity is not very important for refining operations. However, the effective viscosity of the emulsion depends largely on the volume fraction of water and the temperature phases in thermodynamic equilibrium. In this connection, the previous research work guides in developing correlations to predict the actual values of viscosities [6]-[9].

The main objective of this study is to examine the rheological properties and characteristics of light crude oils. The work is divided into three sections. The first part examines the behavior of light crude oil flow with effect of temperature. The second part verifies rheological models such as Hershel-Bulkley to simulate the flow behavior of emulsions. The third part evaluates various parameters of emulsions at different percentages of water such as: yield stress, flow index.

II. EXPERIMENTAL PART

A. Materials

In this study four different samples of light crude oil were used for the preparation of emulsions. These samples of light crude oil were taken from different oil fields in Algeria. At temperature of 20 °C, the samples were characterized by a density of 800 kg/m^3 and a specific gravity (API) between 38 and 48. The emulsions were prepared with different concentrations of water (50% and 70%).

III. RESULTS AND DISCUSSION

A. Rheology of light crude oils

The flow behavior of two light crude oil samples were investigated over a wide range of shear rates ranges from 20 °C to 50 °C. Test was piloted under controlled rate mode and the values for shear stress and shear rate were obtained. The typical rheograms in terms of shear stress and shear rate are shown in Figs. 1-2. Their result showed that shear stress increased and significantly with the shear rate. Rheological model of Newton according to Eq. (1), was investigated in this study.

$$\tau = k\dot{\gamma} \tag{1}$$

Where τ is the applied shear stress in Pa and $\dot{\gamma}$ is the corresponding shear rate in s-1, the k of Eq. (1) is consistency in Pa.sn, (see Table I).

M. Meriem-Benziane is with the Department of Mechanical Engineering, University Hassiba Benbouali of Chlef, Algeria (phone : 213-791835640; fax :213-27721794; e-mail : mbmadid2001@yahoo.fr)

Sabah A. Abdul-Wahab is with College of Engineering, P.O. Box 33, Sultan Qaboos University, Al-khod 123, Sultanate of Oman, (e-mail: sabah1@squ.edu.om)

H. Zahloul is with the Department of Mechanical Engineering, University Hassiba Benbouali of Chlef, Algeria, (e-mail :zahloulh@yahoo.fr)

M.Belhadri is with the Laboratory of Rheology, transport and Treatment of the complex fluids, University of science and technology- Mohamed Boudiaf, B.P.1505, El M'Naour, Oran-31000 Algeria, (e-mail :mbelhadri@yahoo.fr)

TABLE I
UNITS FOR RHEOLOGY PROPERTIES

SYMBOL	QUANTITY	SI UNIT
τ_0	yield stress	Pa
n	flow index	-
$\dot{\gamma}$	shear rate	s-1
τ	shear stress	Pa
k	consistency	Pa.sn

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Result showed the effect of temperature on viscosity shear rate for light crude oil over the range of 10 °C to 50 °C. The shear stress has been decreased considerably with temperature.
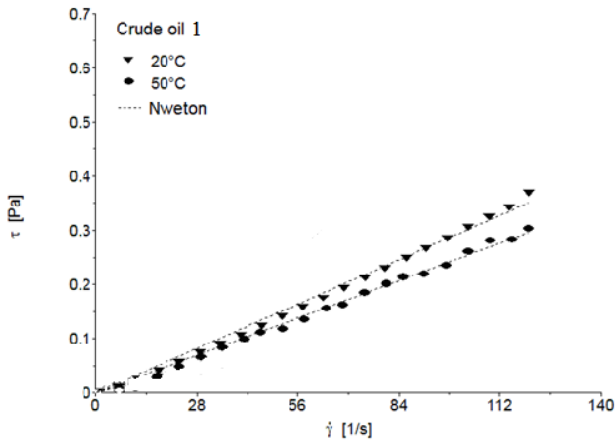

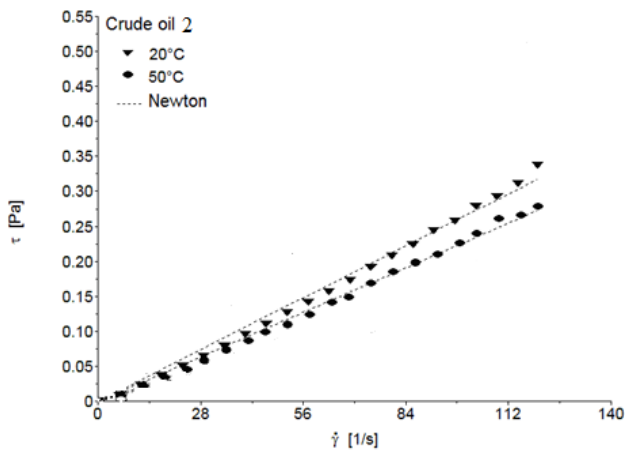Fig. 1 Rheogram of light crude oil 1 for different temperatures

Fig. 2 Rheogram of light crude oil 2 for different temperatures

B. Flow behavior of light crude oil -water emulsions

In this study, the emulsions with different concentrations were used in the samples of drilling fluid. The relationship between shear stress and shear rate for the emulsions with different light crude oil concentrations (30% and 50%) have been designed as shown in Figs. 3 and 4 respectively. Rheological model Herschel-Bulkley is investigate in this study as shown by Eq. (2). The results obtained from modeling analysis have been reported in Figs. 3 and 4 respectively.

$$\tau = \tau_0 + k\dot{\gamma}^n \qquad (2)$$

Where τ_0, n and $\dot{\gamma}$ of Eq. (2) are the yield stress in Pa, flow index and the shear rate s-1 respectively, (see Table I).
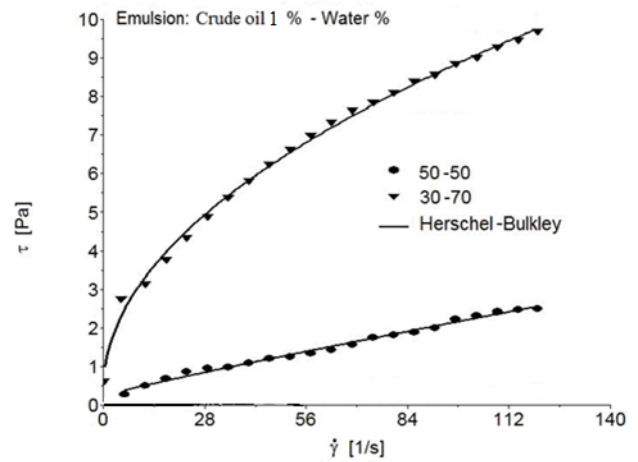

Fig. 3 Rheogram emulsion of light crude oil 1 at different water contents
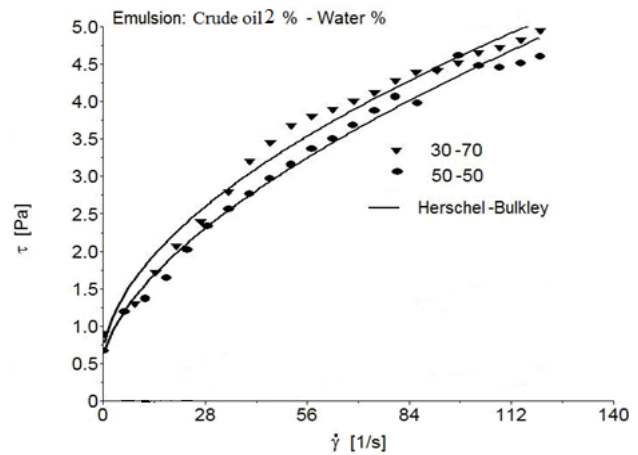

Fig. 4 Rheogram emulsion of light crude oil 2 at different water contents

The parameters which were started from the curves of flow as estimated by Hershel–Bulkley, have presented the coefficients with correlation of 0.99. From Figs. 3 and 4 of emulsions 1 and emulsion 2, it has been found that Herschel–Bulkley model has more accurate.

Thus, it was concluded that with the availability of adequate experimental data, this model will result with more accuracy.

C. Impact of water volume on yield stress and coefficient of index n

The Fig. 5 showed, the yield stresses τ_0 associated with the emulsions of light crude oils (1 and 2) showed higher values. It can be observed that their values increased with the concentration of water and can be reached up to a maximum limit of 0.6 Pa regardless upon of crude oils. Thus, a conclusion can be made that the rheological behaviour of yield stresses are similar to plastic fluid (Herschel-Bulkley).

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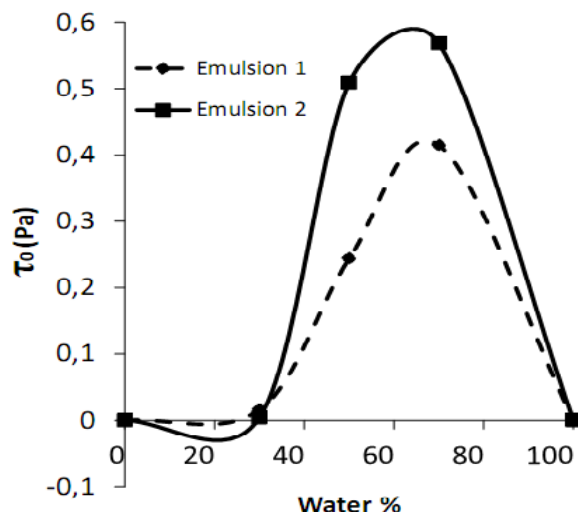Vol:6, No:7, 2012

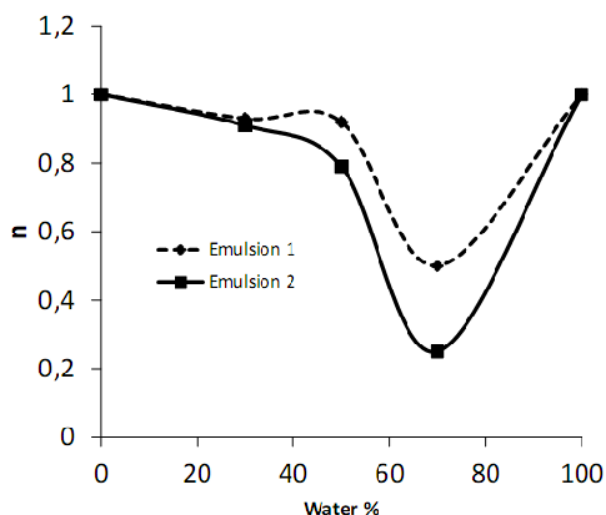Fig. 5 Evolution of the yield stress with the concentration of water

Fig. 6 Development of flow index n in function of the water
concentration

From Fig. 6, it can be seen that the value of flow index has been decreased with high volume concentration of water and its value would be definitely less than unity regardless of the light crude oil.

Moreover it can be remarked that the fluids showed non-Newtonian behaviour particularly in the range of 0.25 to 0.9 because the coefficient n was less than 1.

D. Influence of water contents on the rheology of emulsions

The knowledge of the rheological behavior of emulsions is necessary for flow modeling analysis. In this study, the four samples of light crude oil were used for the preparation of emulsions with different water contents (50% and 70% water contents). After preparation of emulsions, the rheological tests were performed on them. According to the water concentrations, the rheological behavior of these emulsions (oil-water) was modeled according to the main laws of the rheology of complex fluids.

IV. CONCLUSION

In this work, we have investigated a problem which was correlated for improving emulsion's recovery in oil field. The first objective of this work was to study the different parameters of rheograms such as shear stress-shear rate at different temperatures for light crude oils. On the main of this study, a showed was made that the light crude oil exhibited Newtonian flow behavior for a lower temperature range (10 °C to 50 °C). The second aim of this work was to study different parameters of the rheograms such as shear stress, yield stress and flow index of different emulsions for enhancing the flow properties.

The study presented that various emulsions of light crude oil-water exhibited non-Newtonian flow behavior of shear thinning (n<1) profiles. They were also represented in a better way by the Herschel-Bulkley model.

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