Rheological Approach to the Development of a Reference Fluid Mimicking Crude Oil Behavior

Galina Rodionova[1], Johan Sjöblom[1], and Svetlana Derkach[2]

[1] Norwegian University of Science and Technology (NTNU), Trondheim, Norway
[2] Murmansk State Technical University, Murmansk, Russia

ABSTRACT

Viscosity measurements of water-in-oil (W/O) emulsions at a wide range shear rates, droplet size distributions and separation profiles of the emulsions were used as tools for predicting if the reference fluid and crude oil will have similarities in the flow properties when subjected to actual pipeline conditions.

INTRODUCTION

Crude oil itself is a toxic, volatile product that requires safe transportation and special routines in laboratory conditions. Testing large amounts of such oils, for example, to compare efficiency of different equipment, might be problematic due to high flammability and other safety issues. A reference fluid, also referred to as model oil, can be prepared to mimic crude oil and emulsion properties at various conditions. For industrial applications, mimicking flow properties of the crude oil and formation/separation of emulsions are of primary importance.

In this study, a research effort was undertaken to develop a reference fluid modelling separation profile of W/O (water-in-oil) emulsions, rheological properties and pipeline flow behavior. The flow regime was confirmed on the preassigned shear rate interval. The mass flow rate, pressure drop and in-situ droplet sizes were recorded after reaching a steady state condition in the pipeline. As for emulsion preparation, different surfactant amounts, polymer mixtures and aqueous volume fractions were investigated to determine viscosity (rheological behavior), stability and emulsion type. The droplet size distribution profiles of emulsions prepared in batches were estimated using a nuclear magnetic resonance spectroscopy (NMR), while in the pipeline droplet size distribution profiles were registered in-situ by a focused beam reflectance measurement probe (FBRM)[1].

MATERIALS AND METHODS

Crude oil

The heavy crude oil sample used in this study had 19°API. The oil was characterized with respect to ASTM D2007 SARA (Saturates, Aromatics, Resins and Asphaltenes) analysis, emulsified water content, density, total acid number (TAN) and total base number (TBN).

Preparation of the Reference Fluid

The chemicals used in the preparation of the reference fluid were identified through a systematic testing. The final composition contained Primol 352 and polyisobutylene.

Preparation of Emulsions

Crude oil and reference fluid W/O emulsions were prepared in a constant temperature water bath at 60°C. Emulsification was performed in batches of 25 mL using a variable speed Ika® - Werke Eurostar digital homogenizer (Ika® - Werke

Co., Germany) and aqueous phrase volume fractions from 0 to 0.7. At constant speed of 2000 rpm using a 4-bladed propeller stirrer, the emulsions were obtained after 15 min of treatment. The emulsifier SPAN 83 was added to the reference fluid oil phase and left on a magnetic stirrer for 24 hrs before emulsification.

RESULTS AND DISCUSSION

Rheological properties of the heavy crude oils with large presence of asphaltenes are highly sensitive to the interactions between its components under applied shear rates and temperatures. The steady-shear experiments were realized on the current crude oil sample, and flow curves at temperatures from 0 to 60°C and shear rates from 0.1 to 1000 s^{-1} were recorded (Fig. 1).

The emulsion rheology may vary between the crude oil and reference fluid. Presence of the emulsifying agent is another important factor. The common trend of higher viscosity was observed at increasing water content in the emulsions for both fluids.

Although small differences can be observed from the graph, both the reference fluid and crude oil emulsions displayed a similar shear-thinning behavior at shear rates varying from 100 to 1000 s^{-1}. The magnitude and gradient of the shear thinning stays similar for both emulsions as the water fraction increases.

CONCLUSION

Viscosity measurements at a wide range shear rates, droplet size distributions and separation profiles of the emulsions were used as tools for predicting if the reference fluid and crude oil will have similarities in the flow properties when subjected to actual pipeline conditions. The effective viscosities of the emulsions estimated during pipeline flow tests showed a similar behavior as the aqueous phase volume fraction increased.

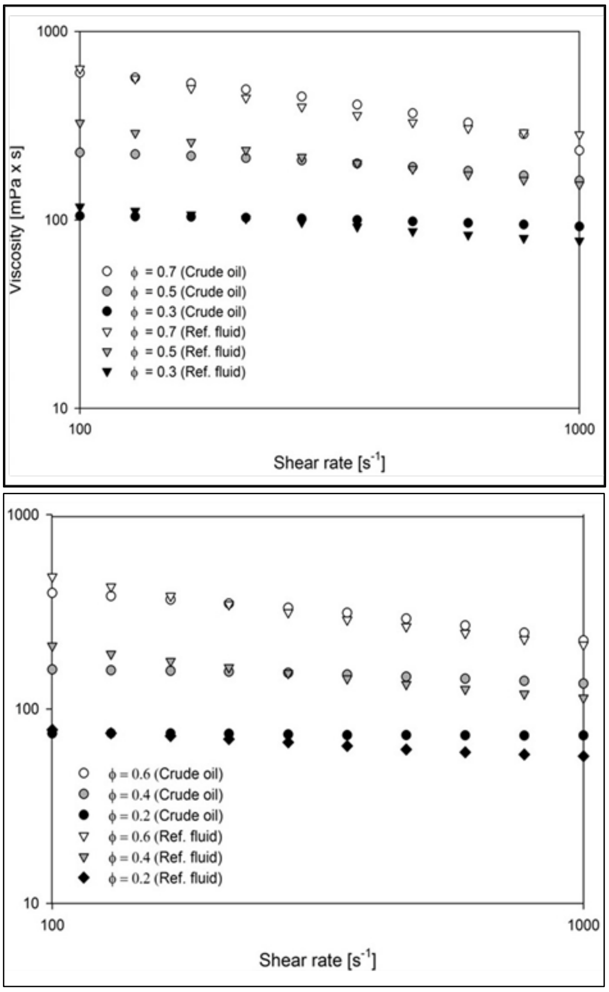

Figure 1. Flow curves of the crude oil and reference fluid emulsions at concentrations of aqueous volume fractions (ϕ) from 0.2 up to 0.7 and 60°C

ACKNOWLEDGMENTS

The work was supported by the Russian Foundation of Basic Research (project N 16-58-20008).

The authors acknowledge the partial financial support from The Multiphase Flow Assurance Innovation Centre (FACE) and Russia and the High North/Arctic (NORRUS) programme.

REFERENCES

1. Rodionova, G., Pettersen, B., Kelesoglu, S. and Sjöblom, J. (2014), "Preparation and characterization of reference fluid mimicking behaviour of North Sea heavy crude oil", *Fuel*, **135**, 308-314.