Petroleum Science and Technology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lpet20

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Published online: 19 Mar 2012.

To cite this article: O. A. Adeyanju & L. O. Oyekunle (2012) A New Unified Model for Predicting Non-Newtonian Viscosity of Waxy Crudes, Petroleum Science and Technology, 30:9, 904-914, DOI: 10.1080/10916466.2010.494094

To link to this article: http://dx.doi.org/10.1080/10916466.2010.494094

Petroleum Science and Technology, 30:904–914, 2012

ISSN: 1091-6466 print/1532-2459 online
DOI: 10.1080/10916466.2010.494094

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A New Unified Model for Predicting Non-Newtonian Viscosity of Waxy Crudes

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Abstract *Viscosity determination in the non-Newtonian regime has always been a major problem in the oil industry. This is due to its dependence on the wax precipitated shear and thermal history of the crude oil. The present shear rate dependent viscosity model was developed by applying the theory of suspension rheology. This model is characterized by its capacity to predict viscosities of crude oils with different shear and thermal history and those containing petroleum-based diluents. Once viscosities at two temperatures above the wax appearance temperature (WAT) and apparent viscosity in the non Newtonian regime are known, viscosities or apparent viscosities at any temperature above the gel point can be determined by using the model together with the concentration of precipitated wax at the specified temperature. Verification of the model by using two Nigerian crudes with different shear and thermal histories and two crudes obtained from the literature shows that the model predicts viscosities with an average absolute deviation of 4.9%.*

Keywords aggregates, dispersed phase, gelation, suspension, Newtonian regimes

1. Introduction

Crude oils contain significant quantities of wax, which can crystallize during production, transportation, and storage, resulting in an increase in viscosity by several orders of magnitude and oil gelation. The compositional dependent models that have been developed (Einstein, 1956; Rutgers, 1962; Graham, 1981; Potanin, 1991, 1993) have only been derived based on pure hydrocarbons and binary hydrocarbon mixtures. Thus, these models are not suitable for petroleum and reservoir fluids due to lack of basic compositional information. Due to this, studies of the viscosity of real reservoir fluid are required. The rheology of waxy crudes is believed to be influenced by wax, resin, and asphaltenes presence (Aboul-Gheit et al., 1997; Singh and Fogler, 1999; Chang et al., 2000), as well as by thermal and mechanical history (Wardhaugh and Boger, 1991a,b; Li and Zhang, 2003).

2. The Effect of Precipitating Wax on Waxy Crude Oil Viscosity

For a Newtonian system in a very dilute regime, the Einstein (1956) equation is applicable, provided the dispersed particles are hard spheres.

$$\mu_r = 1 + 2.5\phi \tag{1}$$

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