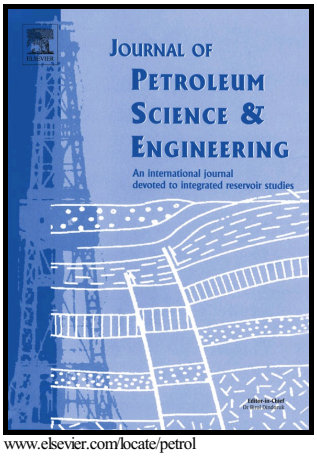

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Rheological properties of heavy oil emulsions with different morphologies

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Abstract

Morphology and rheological properties of emulsions produced from heavy oil and aqueous solutions of surfactants with high hydrophilic-lipophilic balance (HLB) varying from 11 to 40 have been studied. The initial oil containing only trace amounts of water showed Newtonian properties over a wide temperature range (20 to 70 °C). As a function of preparing conditions, surfactant HLB and amount of aqueous solution, stable emulsions with different morphologies were formed: water/oil (W/O), double $water_1/oil/water_2$ ($W_1/O/W_2$) and $oil_1/water/oil_2$ ($O_1/W/O_2$), as well as multiple emulsions having more complicated morphology. Structural diversity of the emulsions determines the scatter of their rheological properties from Newtonian to visco-plastic. Introduction of aqueous solutions of surfactants with HLB ≥ 15 (Tween 80 and sodium dodecyl sulfate) gives rise to multiple emulsions characterized by a specific structure: ultradisperse W/O emulsion permeated with channels consisting of double $W_1/O/W_2$ emulsions. Such multiple emulsions containing 15 to 25 vol.% of surfactant aqueous solution exhibit non-Newtonian properties. Their effective viscosity at the shear rates typical for the oil flow regime in pipelines is reduced by 10 to 50 times as compared with the viscosity of the initial crude oil, being therefore acceptable for transportation.

Keywords: heavy oil, rheology, viscosity, nonionic surfactants, emulsion morphology, multiple emulsions water/oil/water type, visco-plastic media

1 Introduction

According to some estimates (Alboudwarej, 2006), the world resources of heavy oil and natural bitumen considerably exceed those of light oil. The development of heavy oil resources pushes to new economically viable technologies of their production, transportation, and subsequent processing. Heavy oils are oils with a relatively low value of API gravity, which depends on the ratio of oil and water densities. API gravities of 10 to 22.3 correspond to heavy oils, and API gravities less than 10 (which means that oil is denser than water) correspond to super-heavy oils (Conaway, 1999).

Composition of heavy oils is conditioned by biodegradation processes that took place over geologic time. An example is enrichment of heavy oil with resins, asphaltenes, and polyaromatic compounds as a result of activity of microorganisms (Head et al., 2003). Besides, the loss of light fractions may be caused by elution and phase fractionation.

The water is a persistent and inevitable component of crude oil, both in natural state of occurrence and during production. Initially, oil and water exist as two separate phases. However, their movement along wellbores, pipes, through valves and pumps results in the formation of emulsions. Crude oil of any type is