

Dynamic interfacial tension in surfactant enhanced alkaline flooding

KEVIN C. TAYLOR, BLAINE F. HAWKINS and M. RAFIQ ISLAM*
Petroleum Recovery Institute
Calgary, Alberta

ABSTRACT

Dynamic interfacial tension behaviour has been identified in a surfactant-enhanced alkaline flooding process using David Lloydminster crude oil, sodium carbonate, and the surfactant Neodol 25-3S. The magnitude of this dynamic behaviour was found to vary with the surfactant concentration.

Five linear corefloods in Berea sandstone were performed with different Neodol 25-3S concentrations. It was found that the initial interfacial tension value in each system, measured with the spinning drop apparatus, correlated with oil recovery efficiency. Further confirmation of this effect was found by comparison with literature values of oil recovery vs capillary number for linear Berea sandstone corefloods.

Introduction

In this paper, dynamic interfacial tension is shown to occur in surfactant-enhanced alkaline flooding. In such a process, the interfacial tension that occurs after initial oil/aqueous phase contact changes with time. The effect that this dynamic behaviour has on oil recovery in linear Berea sandstone cores is demonstrated.

Dynamic interfacial tensions can occur when two immiscible liquid phases come into contact, provided one or both of the phases contains a surface-active material. Interfacial tension between the two phases can change continuously with time until an equilibrium value is reached. During the course of attainment of equilibrium, the system may pass through an interfacial tension minimum. The possibility of this type of behaviour was mentioned by Wilson⁽¹⁾ and by Harkins⁽²⁾ in the 1920s. In 1952, the phenomenon was observed by Mansfield⁽³⁾ with nujol/oleic acid in contact with a caustic solution, using the pendant-drop apparatus. England and Berg⁽⁴⁾ described dynamic interfacial tension as the result of adsorptive accumulation of surface-active species at the interface, and observed the presence of adsorption and desorption barriers for the transfer of 1,5-pentanediol from white oil to water.

Dynamic interfacial tensions have been observed repeatedly for crude oil/caustic systems. The phenomenon of interfacial tension (IFT) reduction in this system was first reported by Atkin-

son⁽⁵⁾ and Nutting⁽⁶⁾ in 1927. A more detailed investigation was carried out by Reisburg and Doscher⁽⁷⁾, who looked at the effect of interface age and of sodium hydroxide concentration on interfacial tension. Jennings⁽⁸⁾ examined 164 crude oils from 78 oil fields and measured IFT as a function of sodium hydroxide concentration using the pendant-drop method. He defined the term "caustic coefficient" as "the number of square cycles on log-log paper bounded by the caustic interfacial tension curve between interfacial tension values of 0.01 and 1.0 dyne/cm and caustic concentrations between 0.001 and 1.0 wt%". A poor correlation between caustic coefficient and crude oil total acid number was found. However, 90% of the oils tested showed their lowest IFT with a sodium hydroxide concentration of 0.1 wt%. Jennings did not measure dynamic IFT behaviour.

McCaffrey⁽⁹⁾ measured IFT between sodium hydroxide solutions and four crude oils using the spinning drop method⁽¹⁰⁾. In some cases he found that IFT increased dramatically as the interface aged, which he attributed to the migration of soap products away from the interface after their initial formation. Using the spinning drop method, he was able to record dynamic IFT behaviour more readily than with the pendant-drop method. Most subsequent studies of low dynamic IFT values have relied on this method.

Rubin and Radke⁽¹¹⁾ were the first to present a physical model to explain the dramatic IFT decrease that can occur during the contact between an acidic crude oil and an alkaline aqueous phase. They rationalized this behaviour by postulating the existence of a desorption barrier for surface-active species at the oil/water interface. In their model, reaction of acidic surface-active materials in the crude oil with sodium hydroxide in the aqueous phase was assumed to occur rapidly at the interface, but desorption of these species was taken to be slower. This would lead to a maximum in the concentration of surface-active species at the interface at some point in time and hence an interfacial tension minimum. Subsequently, IFT would increase as equilibrium is approached. Because the model is a physical one, the effect on IFT of changes in aqueous phase composition is not taken into account.

Sharma and Yen⁽¹²⁾ have described a chemical model accounting for IFT variations with changes in pH, salinity, and temperature. However, they do not specify at what time their IFT measurements are recorded, only that they are at equilibrium. Their model does not take dynamic IFT behaviour into account. In a following paper, Sharma, Jang, and Yen⁽¹³⁾ attempt to model the dynamic IFT behaviour using both a one- and a two-component model. In this approach, they postulate that a surface reaction of acid species produces interfacially active species

*Now with NOVA HUSKY Research, Calgary, Alberta.

Keywords: Surfactant enhanced alkaline flooding, Dynamic interfacial tension, Capillary number, Berea sandstone, David Lloydminster.

Only page 1 of this paper is provided for copyright reasons. For more information, please contact:

Kevin Taylor, B.Sc., M.Sc. (Chemistry), PChem
Taylor Industrial Research, Inc.
Tel: 250-418-5705 Fax: 250-361-0099
Email: kevin.taylor@industrialresearch.ca Website: www.industrialresearch.ca