INTERFACIAL EFFECTS IN THE RECOVERY
OF RESIDUAL OIL BY DISPLACEMENT:
STUDIES AT NORTHWESTERN UNIVERSITY

Quarterly Technical Progress Letter
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OBJECTIVE A: Effect of Surface Viscosities

Our long term objective is to quantify the relative effects upon displacement of interfacial tension, the interfacial viscosities, wettability, and contact angle hysteresis.

Our short term objective is to determine the effects of the interfacial viscosities during the displacement of a gas by a liquid in a straight capillary tube. We have outlined two methods of obtaining this solution. The first method involves an iterative solution of an integral equation, which was explained in our recent annual report. We are at an intermediate stage in programming this solution, having successfully passed our initial tests. The alternative method of solution employs newly developed bounding principles which allow us to compute upper and lower bounds for the rate of dissipation of energy within this system. The rate of energy dissipation is easily related to the pressure drop over the system and the speed of displacement of the phase interface.

We have had some success with a related problem.

A qualitative analysis has been developed to explain the roles of surface tension and the two surface viscosities in the displacement of foams through porous media. There is a critical value of the surface tension above which a foam cannot be displaced. The displacement efficiency of a foam can be raised by increasing the surface tension to only slightly less than its critical value, by increasing the viscosity of the aqueous surfactant solution from which the foam is formed, and by increasing the surface viscosities. These predictions are in agreement with available experimental data. The agreement between the effect of the surface viscosities on foam displacement predicted and that observed experimentally

by Kanda and Schechter (1976,1977) gives added support to the predictions of a similar analysis (Slattery 1974) regarding the effects of the interfacial viscosities in the recovery of residual oil by surfactant water-flooding.

Kanda, M., and R. S. Schechter, "On the Mechanism of Foam Formation in Porous Media," paper SPE 6200, Society of Petroleum Engineers of AIME, 6200 North Central Expressway, Dallas, Texas 75206 (1976).

Kanda, M., and R. S. Schechter, "The Insitu Production of Foams in Porous Media," currently being reviewed (1977).

Slattery, J. C., "Interfacial Effects in the Entrapment and Displacement of Residual Oil," AICHE J. 20, 1145 (1974).

OBJECTIVE B: Measurement of Surface Viscosities

Our primary objective here is to begin measuring the oil-water interfacial shear viscosity as a function of salt and surfactant concentrations in the aqueous phase, of equivalent alkane carbon number for the organic phase, and of interfacial tension. At least initially, we will use the experiment with the deep channel surface viscometer suggested by Hegde (1971) and recently demonstrated as feasible by Deemer (1976).

We hope that within the next month we will be able to place the order for the optical and photographic equipment required to improve the deep channel surface viscometer.

Meanwhile, we are attempting to finish with Dr. Charles Thomas and Dr. P. D. Fleming of Phillips Petroleum Company, the analysis of the spinning drop surface viscometer. This is the spinning drop interfacial tensiometer with a small oscillatory perturbation imposed on the angular velocity of the tube. One might measure either the amplitude of the oscillation of the drop or the phase lag between the oscillation of the tube and the oscillation of the drop. This may ultimately prove to be a more satisfactory experiment for measuring interfacial viscosities than the deep channel.

In the process of considering the spinning drop surface viscometer, we have developed an alternative solution for the spinning drop interfacial tensiometer. This solution, while in agreement with those published previously is somewhat easier to use by an experimentalist.

Hegde, M. G., Ph.D. Dissertation, Northwestern University, Evanston, Illinois (1971).

Deemer, A. R., Ph.D. Dissertation, Northwestern University, Evanston, Illinois (1976).

Objective C: The Measurement of Small Interfacial Tension by the Rod-in-Free
Surface Meniscal Breakoff Method

During this quarter (March 1 to May 31, 1977) the following activities were pursued: (1) The Barotron" (MKS Instruments) capacitance pressure transducer was delivered and incorporated into the meniscal breakoff tensiometer; (2) the static pressure analysis used to interpret the breakoff data from the transducer was improved; (3) interfacial tension measurements over extensive periods of time with an (octane)/(0.2% Witco TRS 10-80 in 1% NaCl aqueous solution) system were taken with both the meniscal breakoff and spinning drop tensiometers.

The new pressure transducer appears to be operating satisfactorily insofar as indicating breakoff (see Annual Report, ERDA Contract No. EY-76-S-02-0039, page 11). It was, however, hoped that it could be used in a more comprehensive mode; the improved theory for static pressure variations shows that accurate pressure measurements as well as breakoff detection would yield additional information. It can be shown that one can obtain the density difference between the two phases and the undisturbed interface position by merely reading pressure versus interface traverse. Thus, in one measurement (pressure vs interface position) all data necessary to infer the interfacial tension can be obtained. This is desirable since there is concern that transient processes (such as mass transfer to the interface) persist over long periods of time; the ability to monitor changes in density difference and interface position due to such transfer processes may, therefore, be important.

To date, accurate measurements of pressure differentials have not been successful. This is due to thermal and atmospheric transients which

cause pressure excursions of the same order of magnitude as those required in the experiment; this is particularly true when the breakoff is achieved over a long time interval (> 15 to 30 minutes). Efforts are being directed to overcome these disturbances.

It should be emphasized that the breakoff detection is not impaired by these thermal and/or atmospheric perturbations. A separate procedure has been successfully introduced that allows determination of the undisturbed interface position. The breakoff is then readily observed as a large, relatively sudden pressure excursion on a strip chart recorder.

Data (still of a preliminary nature) on interfacial tension with the octane/Witco system previously noted has been collected by both meniscal breakoff and spinning drop tensiometers. Attention was focused on the long-time approach to equilibrium of equilibrated hydrocarbon and aqueous phases. It was found that even after 300 hours of spinning interfacial tension (IFT) still appeared to be decreasing. The meniscal breakoff method gave much slower variations of IFT over the first 300 hours of observation. These results must be checked and rechecked before definitive statements are attempted.

A preliminary theoretical development of mass transfer effects on the spinning drop experiment has been formulated. Efforts toward further understanding will be made during the next quarter.