The Physics of Soft and Biological Matter

Asphaltene deposition in microfluidic capillary flow experiments and particulate computer simulation

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Carbon dioxide (CO_2) flooding is being increasingly used for Enhanced Oil Recovery operations in depleted oil reservoirs. However, in some cases, CO_2 injection may lead to asphaltene precipitation from crude oil. Asphaltene precipitation and deposition in reservoir rocks may cause a decrease in the crude oil recovery efficiency due to reduced permeability and porosity of the reservoir rock. Asphaltene deposition is one of the costliest technical problems the oil industry has to deal with.

Despite a significant research effort, there are still limitations for predicting the asphaltene deposition in reservoir rocks. It is not yet fully identified how asphaltenes behave in reservoir rocks during laminar flow under precipitating conditions.

The microfluidic technology offers the possibility to study colloidal flow properties at low Reynolds numbers and to understand the influence of asphaltene deposition on flow properties in real reservoir rock. Thus, oil recovery rates from asphaltenic reservoirs could be optimized.

In our work, we have been studying the process of deposition from a crude oil/toluene mixture in microfluidic capillary flow experiments. This mixture is co-injected into a glass capillary with *n*-heptane, an analogue fluid for CO_2 giving rise to potential asphaltene precipitation and deposition. This enables optical observations of the deposition process using a state of the art confocal laser-scanning microscope. Simultaneously, we monitor the pressure drop as a function of time following the impact of deposition on permeability. The work builds on recent work by Boek et al. (2010) [1]. Here we extend this work by considering capillaries packed with glass beads as a more realistic approximation for flow in porous media due to reduced porosity and permeability.

We investigate the effect of flow rate and ratio of *n*-heptane/crude oil to toluene on the rate and amount of asphaltene deposition. With higher ratio, the rate of asphaltene precipitation increases, thus leading to a higher deposition rate. Deposition of asphaltenes was limited as the pressure levelled off. This suggests erosion/entrainment of deposited asphaltenes. Different flow regimes were investigated: we observe that the pressure drop increases with decreasing flow rate. Optical images (Figure 1) and experimental mass determination have confirmed that the mass of deposited asphaltenes increases with increasing flow rate, indicating that adsorption forces are dominant over hydrodynamic forces. Fluid mechanics theory and particulate simulation were used to explain these new results. The results obtained for the pressure drop measurements were confirmed by Stochastic Rotation Dynamics (SRD) computer simulations [1].

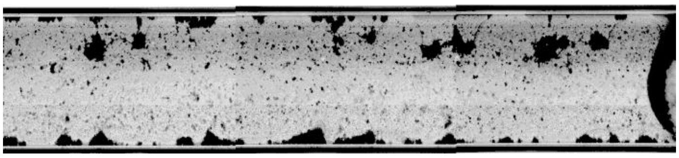

Figure 1. 3.9 mm section of a micro glass capillary with deposited asphaltenes (black spots), located near to the entrance of the capillary on the right hand side [2].

[1] Boek, E.S., Wilson, A.D., Padding, J.T., Headen, T.F., Crawshaw, J.P. (2010) Multi-Scale Simulation and Experimental Studies of Asphaltene Aggregation and Deposition in Capillary Flow, *Energy&Fuels*, 24, 2361-2368

[2] Seifried, C.M., Al Lawati, S., Crawshaw, J.P., Boek, E.S. (2013) Asphaltene Deposition in Capillary Flow, *SPE 166289*, presented at the SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, USA, 30 September – 2 October 2013