Simulation of surfactant transport onto a foam lamella using material point method

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The transport of surfactant onto a foam lamella in a foam fractionation column with reflux is simulated mathematically. Assumptions made for the simulation are that the lamella is flat due to the bubble shape in a dry foam – a common situation in a foam fractionation column, the initial surfactant concentration on the film surface is uniform and the surfactant concentration at the Plateau border is held fixed at the value set by the reflux. There are two terms involved in the equation for surfactant flux which are the Marangoni flow – from the Plateau border to the centre of the lamella – and the film drainage – which is directed from the centre of the lamella to the Plateau border. The extent of film drainage is bounded using two extremal assumptions of mobile [1] or rigid [2] interfaces. On a mobile interface, the film drainage dominates the Marangoni effect, while on a rigid interface, the Marangoni effect is dominant. The numerical simulation was carried out using a material point method [3] followed by a bookkeeping operation to regrid the film.

The surfactant transport in the case of no drainage is modelled as a benchmark for the case with film drainage. For this 'no drainage' case, the simulation results well agree with the analytical solutions obtained from complementary error function and Fourier series. The simulation results assuming a film with a rigid interface fits well with the analytical (quasi) steady solution at later time. An asymptotic boundary layer model for surfactant transport on a film with mobile interface verified the simulation results. From the simulations, it can be concluded that the film drainage obtained using surfactant with a mobile interface is much faster than that modelled using surfactant with a rigid interface, meaning that surfactant is washed out of the film in the mobile case. The desirable condition in a foam fractionation column is however where the Marangoni flow dominates the liquid drainage – therefore surfactant accumulates on the film surface – which can be achieved when using surfactant that gives a rigid interface.

Literature:

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