2D micromodel observations of foam flow regimes and flow diversion

C.Yeates[a], S. Youssef[a], L. Nabzar[a]

[a]*Département Géofluides-Roches, IFPEN, 1-4 Avenue du Bois Préau, 92852 Rueil-Malmaison*

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The use of foam as an injection fluid in reservoir engineering shows great promise in overcoming problems often encountered in traditional gas or liquid injections. The viscosifying effect of foams serves initially as mobility control in comparison to gas-only injections, by reducing the incidence of viscous instabilities at the injection front. Perhaps more compelling is the ability of foams to overcome reservoir heterogeneities, which lead to the creation of preferential flow paths and also contribute to a non-uniform displacement front. Improvement of the volumetric sweep in heterogeneous reservoirs is therefore a core motivator in the use of foams and understanding the dynamics of foam flow in porous media becomes paramount.

Multiple mechanisms have been proposed to explain the counter-intuitive diversion of injection fluids into low-permeability areas of the reservoir through the use of foams. The diversion of injection fluids into low permeability areas has been explained by the interplay of multiple foam flow regimes. Specifically, high (high gas content) and low (low gas content) quality regimes have been observed that both have distinct rheological properties. The high quality regime is shown to exist in high capillary pressure environments [1], and lamella density is constantly equilibrated by in situ creation and destruction of lamellae. In this regime the creation mechanisms of foam lamellae become important to maintaining the foam stability. On the other hand the low quality regime demonstrates a stable flow of lamellae through the medium and maintains a bubble density of around 1 per pore. The lamellae instability in the high capillary pressure zones creates a lower lamella density and lower subsequent apparent viscosity and resistance to arriving fluid. We conjecture that this effect is responsible for the diversion of foam into low permeability areas. In addition to this, the transition between each flow regime can be defined at a precise transition foam quality[2] at which the foam rheology abruptly changes[3].

To clarify the role of pore network microstructure in the foam flow dynamics we observe quantitatively and qualitatively the different flow regimes within 2-dimensional micromodels. The use of a carefully optimised AOS surfactant formulation assumes the role of foamer and is coupled with nitrogen at a series of different injection rates. A surrounding high-pressure environment is also imposed by a backpressure regulator. Observed foam textures and auto-correlation profiles extracted from high-framerate camera images of the system provide quantitative data on the stability and mobility of bubbles to be associated with the flow regime for given injection rates. The micromodels used are: a homogeneous hexagonal lattice of identical grains, a "heterogeneous" model of a random distribution of grain locations and sizes, and a multiple zone model of a fracture and two surrounding permeability networks. Qualitative observations include observation of diversion mechanisms between areas of differing permeability.

Overall the aim of this work is to further understand the flow mechanisms of foam in heterogeneous porous media, application is essentially limited to foam injections in oil reservoirs in the context of enhanced oil recovery (EOR).

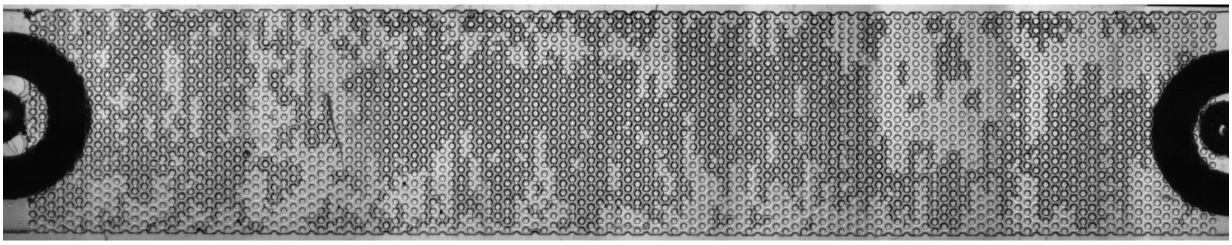

Figure 1: Presence of two phase flow (no surfactant) in the homogeneous hexagonal lattice model with an entry zone (left) and an exit zone (right). The gas phase is in dark grey whereas the liquid phase is of a lighter colour.

References

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