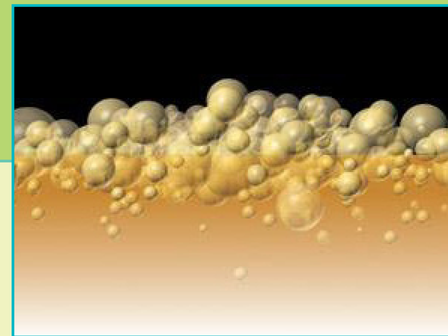
Math Matters

Apply It.

The math behind... Foam



Technical terms used:

Foam lamellae, porous media flow, dynamic population balance models, local equilibrium methods, temporal oscillations

Uses and applications:

Foam is generated in an oil reservoir to increase the production of oil. This method has many advantages over common oil recovery methods, like water or gas injection.

How it works:

When gas is injected into a reservoir of porous rock, it tends to create a shortcut from the injection to the producer well, so that it only pushes out part of the oil. Therefore, water and surfactants (soap) are also injected to form the lamellae, thin water films that separate the gas bubbles from each other. Because the gas is trapped between the lamellae, it won't be able to create a shortcut and spreads more evenly over the reservoir. Hence more oil will be produced.

Because this expensive process takes several years, reliable computer simulations are needed to optimize the oil profit. To answer this need we can choose between two classes of foam models: Dynamic population balance models, which take into account the strength (bubble density) of the foam, and local equilibrium models, which incorporate the effect of the foam through a limit function. The first class of models tries to capture the real dynamics of the process, while the second class assumes that there is only one equilibrium in foam strength.

Local equilibrium models are based on conservation laws for the fluid phases (usually gas, water, and oil), while it is assumed that the surfactant is dissolved in the water phase. Foam is modeled as a reductive effect on the gas mobility, which takes place as soon as the gas comes into contact with a sufficient amount of water and surfactant. Due to this sudden transition between gas and foam, the numerical solutions suffer from nonphysical temporal oscillations and/or instabilities.

Interesting facts:

Foam stability can be studied using population balance models. It depends on many factors, such as gas and surfactant types. For example, Guinness beer has a more stable foam than other beers, because it uses nitrogen gas instead of CO_2.

References:

http://petrowiki.org/Foams

W.R. Rossen, Foams in enhanced oil recovery, in R. K. Prud'homme and S. Khan, ed., *Foams: Theory, Measurements and Applications*, Marcel Dekker, New York (1996).

W.R. Rossen, Numerical challenges in foam simulation: A review. SPE Annu. Tech.

Conf. Exhib., New Orleans, SPE International, New Orleans (October 2013).

Submitted by Jakolien van der Meer, Delft University of Technology, Math Matters, Apply it! Contest, February 2015.

Society for Industrial and Applied Mathematics
www.siam.org
www.siam.org/careers/matters.php