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A Novel Technique of Image Analysis on Foam in Fractures

Monday, 31 May 2021 15:40 (15 minutes)

In enhanced oil recovery, gas injection often suffers from poor sweep efficiency due to conformance problems, such as gravity override, viscous fingering and channelling. Foam, composed of gas bubbles separated by continuous liquid films (lamellae), can effectively mitigate these problems. During foam flooding, the mobility of gas is reduced by a factor of hundreds or even more (Tang and Kovscek, 2006). As a result, the displacement front is more stable, and more gas is diverted to unswept zones, hence improving the sweep and recovery.

The ability of gas mobility reduction of foam is highly dependent on its texture. It has been found that foam with a finer texture implies a greater reduction of gas mobility (Lake et al., 2014). In the laboratory, computed tomography (CT) has often been used to study foam flooding in core plugs (Tang et al., 2019; Gong et al., 2020). The saturation of different phases is mapped, to evaluate the performance of the foam. However, foam texture at the microscopic level is still less understood.

In this study, we present a novel technique of image analysis on foam in two 1-meter-long model fractures (analogous to microfluidic porous media). The fractures are made of glass plates (AlQuaimi and Rossen, 2018). Each model fracture has one flat wall and one rough wall. The gap between the two walls represents the aperture of the fracture. The distribution of aperture can be represented as a 2D map of pores and throats. The two fractures have different roughness distributions. One has a roughness in a regular pattern with a hydraulic aperture of 46 μm. The other one has an irregular pattern with a hydraulic aperture of 80 μm.

To quantify the roughness of the fractures, we profile the roughened surface (size: 2 × 2 cm, resolution: 1342 × 1342, pixel length: 14.9 μm) of the glass plate using a digital microscope. The fracture volume of the two models is also measured. The transparency of model fractures allows direct visualization of foam in the fractures, using a high-speed camera. A high-parallelism backlight is used to provide stable lumination for the camera. The whole setup is placed in a tent to avoid outside reflection and refraction.

In this study, 2D image analysis of foam is performed using ImageJ software. We characterize foam texture by quantifying bubble density, bubble size and area fraction of water and gas. We also program macros to compute the velocity of flowing bubble trains. In addition, by using profiling data, we can convert phase area fraction to 3D volume fraction. We can also estimate the capillary pressure in the model fracture. From that we can estimate the lamella surface area available for foam coarsening by gas diffusion. Based on this information we can distinguish when diffusive coarsening stops because bubble pressures are equalized or slows nearly to a stop because bubbles lose contact through lamellae.

Time Block Preference

Time Block B (14:00-17:00 CET)

References

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Primary author: Mr LI, Kai (Delft University of Technology)

Co-authors: Dr WOLF, Karl-Heinz (Delft University of Technology); Prof. ROSSEN, William (Delft University of Technology)

Presenter: Prof. ROSSEN, William (Delft University of Technology)

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