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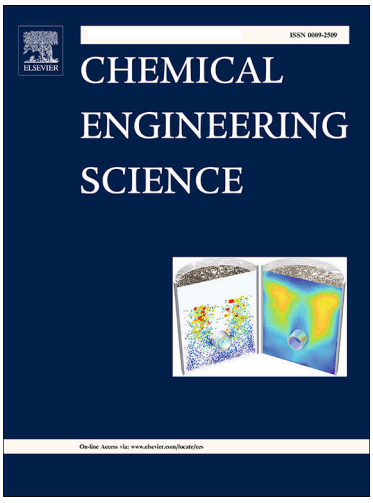

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Studying the generation of foam in the presence of nanoparticles using a microfluidic system

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Abstract

In this paper, a study on the generation of foam in the presence of nanoparticles in porous media using microfluidics is reported. Drainage and co-injection tests were carried out and monitored with a high-speed camera. Convolutional neural network model was applied to quantify foam texture over time, efficiently. Microscopy images show a generation process characterized by early snap-off, followed by lamella-division, and finally leave-behind. In the presence of nanoparticles, the latter stage is delayed due to resistance to drainage imparted by capillary forces within the liquid films. Moreover, a general relationship between the generation rate and the pressure gradient, which resembles the classical constitutive equation for foam generation, i.e., $r_g \propto \nabla P^{\alpha}$, could be formulated. This indicates that the generation of a foam in the presence of partially hydrophobic nanoparticles and anionic surfactant, used for strong foam formation, follows the same mechanism of a foam stabilized only with surfactant.

Keywords: Artificial Intelligence, Bubbles, Foam, Foam generation, Microfluidics, Porous media, Nanoparticles.

1. Introduction

Foam is injected into the subsurface to reduce gas mobility by increasing its effective viscosity and to divert the gas to low permeability zones [1, 2, 3, 4]. It has been employed in enhanced oil recovery (EOR) and in the remediation of contaminated sites [5, 6, 7, 8]. Foam is a complex fluid where the gas phase is segregated into bubbles separated by thin liquid films (called lamellae). The density of the lamellae gives to the foam its texture and its rheological properties. The low mobility of a foam in comparison to the gas and the liquid phase alone, from which it is formulated, is due to the trapped gas saturation and the increased resistance to flow of the gas bubbles [9, 10]. The drag and the resistance to flow of the lamellae through the pores and throats impart the mobility reduction to foam flow. The

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