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Gas Bubble Nucleation of Extra-Heavy Oils in Porous Media: A New Computerized Tomography Technique and Physical Approach

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Abstract

The study of multiphase flow pore level physics has scientific appeal as well as many applications, mainly in oil reservoir engineering. In this work, we show that micro-tomography is an effective tool to extract the structure of many solid systems in a non-destructive and classical manner. Recently, X-ray computed tomography tools have been extended to the ability to contrast fluids in the pore space of core samples.

As time required for collecting a CT image is much longer than almost flow time scales, CT imaging must occur at static flow conditions to accurately geometrical information on fluid-fluid and solid – fluid interaction.

Considering new decisive developments of the visualization cell we claim to have developed a new petrophysical tool which might permit to access experimentally to the visualization in quasi-static flow of the capillary phenomena and multiphase flows analysis in 3D form or in dynamic flow in 2D form. The in-situ measurements are realized in reservoir conditions of extra-heavy oils.

The aim of the measurements is first to contribute to a predictive bubble population balance which will then be integrated in a network flow model computation. This step is required to develop physical models to obtain a more efficient reservoir simulation. More precisely we focus our attention on a quasi static model of bubble nucleation which appears decisive and we demonstrate how to simulate the whole bubble nucleation and the corresponding experimental results to corroborate the experimental observations. We focus here on the influence of the gas availability in the porous media (diffusivity, GOR or porous media morphology).

Introduction

More than a match for energy resources, the productivity of Extra-Heavy oil reservoir is one of the main challenges for oil companies. Numerous Enhanced Oil Recovery processes are available to produce this very viscous and dense oil but primary production techniques are always used. The low environmental and economical cost of the primary production in comparison to steam injection for example is very decisive to select this kind of process.

In primary production we focus our attention on a process called solution gas drive [2]. An Extra-Heavy Oil solution gas drive reservoir is one in which most of the production is due to the expansion of the originally dissolved gas phase [3, 6]. Theoretically oil is undersaturated when reservoir pressure is above the bubble point pressure. Below the bubble point oil is saturated, the gas bubbles form or nucleate at the bubble point pressure and expand with continued decreasing pressure [5]. However the bubble point measured during the experiments, whatever in porous media or in PVT cells, and the bubble density which is the most critical parameter to obtain high OOIP, are mainly dependant on the decline rates. Thus, for higher pressure decline rates, greater numbers of bubbles are formed [4]. The number of bubbles formed was also observed to depend on the gas diffusion rate through the oil which tends to give rise to demonstrate bubble competitiveness and / or Ostwald ripening. Various works on a predictive modeling of bubble density report a need to fit the various parameters [2, 4, 6]. Our objective is to answer to this question that's why we first have been interested in developing a Harvey's nuclei (pre-existent bubble nuclei) model which permits to qualitatively predict or confirm the whole bubble expansion during the depletion [5]. In this way we have been interested in a pore scale approach to confirm this first step.

Pore-scale physics governs fundamental behavior of the upscaled multiphase flows used in reservoir engineering. These systems are very complex and integrate various scientific fields as mechanistic modeling, physical – chemistry, thermodynamics, geology ...

The inability to study direct pore-scale physics, out of very model systems such as 2D micromodels, is usually overcome by a Darcy's law which confers to the modeling a traditional averaging approach. This main approach used in reservoir engineering is mainly based on empirical considerations which are very limited in their applicability and scientifically. The