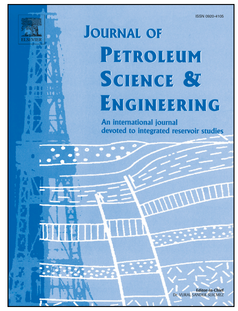

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Flow Physics of How Surfactants Can Reduce Water Blocking Caused by Hydraulic Fracturing in Low Permeability Reservoirs

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Abstract

Significant amount of fracturing fluid is lost after hydraulic fracturing, and it is believed that the loss of fluid into the matrix can hinder the hydrocarbon production. One potential way to reduce this damage is to use surfactants. Robust surfactant formulations have been developed for chemical enhanced oil recovery (CEOR); similar screening methods are introduced in this study to reduce the water block in low permeability reservoirs. Here we present an experimental investigation based on a coreflood sequence that simulates fluid invasion, flowback, and hydrocarbon production within the rock near the fracture face. Real-time CT scans are applied to visualize the change of water saturation profile, which is then compared with the regaining of rock permeability. Different surfactants are used to test the effect of IFT reductions and formation of microemulsions; these are further compared in order to explore the best condition that maximizes the permeability enhancement. From this work, we recognize the main physical mechanism responsible for the potential enhancements after the use of surfactants, thus we suggest criteria to optimize the performance of surfactant additives for stimulating the low permeability gas/oil reservoirs.

Introduction

Hydraulic fracturing is normally applied to stimulate low/ultralow permeability reservoirs in order to obtain an economical hydrocarbon production rate. However, only 5 to 50% of the injected fluid is typically reported to be recovered as “flowback” (Zelenev and Ellena, 2009). Because of this, there is concern that the remaining fracture fluid can hinder hydrocarbon production; this all depends on where the fluid ends up being emplaced in the subsurface. Some fraction of the fluid is trapped within or leaks through the closed induced unpropped fractures (Sharma and Manchanda, 2015), another fraction leaks off into the matrix near the open/propped fractures (Gidley et al., 1990; Javadpour et al., 2015; Wang and Leung, 2016; Wu and Olson, 2016). Since the unpropped fractures are disconnected from the open fractures, this paper concentrates on permeability damage that can be caused by the fracture fluid causing multi-phase flow effects near the open fractures.

Shales or tight sandstones normally have pore throat sizes ranging from tens to hundreds of nanometers (Nelson, 2009), which generate large capillary pressures and can trap the invaded fracturing fluid. It has been reported that the cleanup of water block in tight gas reservoirs would be slowed down when the drawdown pressure is not significantly greater than the capillary pressure/capillary entry pressure (Holditch, 1979; Abrams and Vinegar, 1985; Parekh and Sharma, 2004; Mahadevan and Sharma, 2005; Le et al., 2012). In particular, we reported that matrix-fracture interaction, one form of capillarity, could be mainly responsible for the water block and thus cause significant damage on matrix permeability in such reservoirs which are produced at low flow rates (Liang et al., 2015a; Longoria et al., In Press).

Several surfactant-based fracturing fluid additives have been developed in an attempt to enhance the flowback and gas production (Penny and Pursley, 2007; Zelenev and Ellena, 2009; Rostami and Nasr-El-Din, 2014). Although these studies have reported the enhancements both in the lab and in the field, the physical mechanism responsible for such potential enhancements was not elaborated and thus may be different for tight rocks than capillary desaturation. Moreover, it is also unclear how surfactants affect the flow of hydrocarbon, and what surfactant properties play more important roles during the