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Enhanced Heavy-Oil Recovery by Alkali-Surfactant Flooding

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Abstract

This study presents the results of laboratory core studies investigating the recovery mechanisms of alkali-surfactant flooding in heavy oil reservoirs. Specifically, mixtures of water and alkali-surfactant systems have been injected into cores containing heavy oil (11 000 mPa·s and 15 000 mPa·s). Salinity is varied in order to generate oil-in-water vs. water-in-oil emulsion systems, and the effects of generating different emulsions are compared.

The application of this work is for the many heavy oil reservoirs in countries such as Canada and Venezuela containing viscous oil that still has some limited mobility under reservoir conditions. Alkali-surfactant (AS) flooding has considerable potential for non-thermal oil recovery after primary production.

Experiments were performed on cores with varying permeability, at different AS injection rates. All tests were performed on gas-free oil systems. The response from direct injection of AS systems is compared to AS injection after waterflooding. Pressure and oil recovery information is obtained from core floods, and these results are interpreted based on a semi-theoretical framework obtained from phase behavior and bulk liquid studies. It is demonstrated that both oil-in-water and water-in-oil emulsions can lead to the recovery of additional oil.

Alkali-surfactant flooding is already an established technique in conventional oil reservoirs, whereby enhanced oil recovery is a result of reduced trapping of oil due to the lowered oil/water interfacial tension. In addition, the injection of these chemicals may lead to the formation of emulsions, as has been documented by previous researchers. In our work, we demonstrate that in heavy oil systems, emulsion formation is a necessary requirement for the production of heavy oil. When these emulsions form, AS injection can lead to considerable improvements in the flooding response, even without the addition of polymers to stabilize the flood.

Introduction

Several countries in the world, notably Canada and Venezuela, contain massive resources of unconventional heavy oil and and bitumen. With issues of resource stability and rising oil prices, international interest is now shifting rapidly towards Canada's oil sands. The oil sands are characterized as unconsolidated, high porosity and high permeability reservoirs. While ease of flow is therefore not a significant concern, the single biggest obstacle to successful recovery from the oil sands is the high oil viscosity.

Heavy oil reservoirs are a special subset of the oil sands, whereby the oil viscosity at reservoir temperature and pressure varies on the order of 50 – 50 000 mPa·s (cP). While this oil is still very viscous, it does have some limited mobility at resevoir conditions. As much as 20% of the oil may be recovered by solution gas drive[1], but in many cases the recovery is much lower. At the end of primary production, significant oil still remains in the reservoir, but the reservoir energy has now been depleted. This is the target for enhanced heavy oil recovery.

In order to recover additional heavy oil after primary production, a fluid usually has to be injected in order to displace oil to the production wells. However, mobility ratio concerns dominate displacement of viscous oil, and most EOR processes focus on reduction of the oil viscosity or improvement in the mobility ratio. Unfortunately, many of the heavy oil reservoirs in Canada are relatively small and thin, making them poor candidates for expensive thermal processes. Ideally, the displacement mobility ratio should be improved in an inexpensive (i.e. non-thermal) fashion. This work investigates the potential for alkali-surfactant flooding to be used for enhanced heavy oil recovery.

The injection of alkalis and/or surfactants into oil reservoirs is not a new technology. As early as in the 1920's, Nutting proposed the injection of alkaline solution into reservoirs for oil recovery[2]. The injection of a combination of alkali and surfactant was discussed in the 1950's by Reisberg and Doscher[3]. Since then, chemical injection (alkali and/or surfactant) has become an accepted enhanced oil recovery methodology in many conventional oil applications.

Surfactants are a special class of molecule that are both hydrophobic and hydrophilic, thus the most stable configuration for these molecules is at the oil-water interface[4,5]. In surfactant flooding, these molecules are generally injected along with water in order to reduce the oil-water interfacial tension. This leads to a reduction in capillary forces, that may trap oil in rock pores[6,7]. Alkali flooding is a special subset of chemical flooding, whereby the surfactant is