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Mechanisms of Surfactant and Polymer Enhanced Alkaline Flooding: Application to David Lloydminster and Wainwright Sparky Fields

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Abstract

Laboratory studies have been conducted to identify mechanisms responsible for the observed synergism between alkali and polymer in combined chemical floods. The work focussed on the use of a buffered alkali, sodium carbonate. Coreflood tests conducted with David Lloydminster oil and brine were used for mechanistic studies. The most efficient application of this process required simultaneous injection of alkali and polymer. This permitted both mobilization of residual oil by lowering interfacial tension and displacement of the oil by formation of an oil bank. Oil banking is a very important aspect of the alkali/polymer process. Alkali preflush (i.e. alkali injection prior to polymer injection) leads to reduced recovery in these processes because surface-active precursors are stripped from the oil and are not available to lower interfacial tension during subsequent polymer injection.

Coreflood tests were also used to assess alkali/surfactant/polymer flooding as a tertiary recovery process for the Wainwright field of east central Alberta. Determination of phase behaviour and interfacial tension between Wainwright crude oil and Wainwright brines containing sodium carbonate and several surfactant types led to selection of an optimized chemical slug to use in coreflood studies. Higher tertiary oil recovery from Berea sandstone core plugs compared with preserved reservoir core plugs is discussed in terms of core mineralogy, chemicals propagation and emulsification behaviour. Results are also compared with earlier studies using sodium hydroxide without added surfactant or mobility control agents.

The results indicate that alkali/surfactant/polymer flooding could be a suitable tertiary recovery process for the Wainwright field, and demonstrate the importance of conducting coreflood testing in reservoir core. Excellent response was also observed for the David Lloydminster oil in Berea sandstone core.

Introduction

The mechanisms by which injection of aqueous alkaline chemicals can improve oil recovery have been discussed by several authors[1-4]. The process consists of generation of surface-active materials by the in situ reaction of an aqueous solution of an alkaline chemical with organic acidic components present in the crude oil. The surface-active materials thus generated (referred to as "petroleum soaps") can adsorb at the oil-water interface and lower the interfacial tension (IFT) between the crude oil and the injected water, or they can adsorb on to the reservoir rock surface, thus altering its wettability. Alkaline flooding can be viewed as a two stage process[3], the first stage serving to mobilize residual oil by altering its configuration in the pore space, either through IFT reduction or wettability alteration, with the second stage being the macroscopic displacement of the mobilized residual oil.

Many field projects have been conducted using what we term "classical" alkaline flooding, that is, injection of a solution containing only the alkali. The usual choice of alkali was sodium hydroxide, though sodium orthosilicate has also been used. In spite of encouraging laboratory tests, field performance of this alkaline flooding technology has been disappointing[5-7]. Poor results have been attributed to unfavourable mobility ratio, excessive alkali consumption, and failure to reduce IFT in the reservoir.

Various methods have been proposed to overcome these difficulties. The use of polymer added to either the alkaline slug or the drive fluid can overcome the problem of poor sweep[8]. Excessive consumption of sodium hydroxide can be mitigated by use of buffered alkalis such as sodium carbonate[9], sodium silicates[10], or sodium bicarbonate[11,12]. Commercial surfactant can be used to modify the properties of the petroleum soaps[13,14], to better control IFT in the reservoir.

Nelson et al.[14] treated alkaline flooding as a special case of surfactant flooding. Using a commercial surfactant to augment the in situ produced surfactant, they applied the principles of optimal salinity[15-17] to the design of alkaline floods to determine the appropriate concentrations of alkali and added surfactant which would provide optimum phase behaviour for the system. Taylor[18] used surfactant mixing rules to describe the influence of synthetic surfactant on crude oil/alkali phase behaviour.

A number of laboratory studies have since been reported which study the application of alkali/polymer or alkali/surfactant/polymer flooding to various reservoir systems[19-25]. Indeed, the use of such combined chemicals has become the state-of-the-art in chemical flooding[26,27], and several field pilots have been implemented[28-31].

The improved laboratory results demonstrated by the use of polymer and added surfactant suggested that an assessment of this technology should be undertaken as it related to Canadian reservoirs. There is considerable opportunity for use of alkaline flooding processes in Canada. It has been estimated that there exists an enhanced oil recovery target of some 18 million cubic metres of oil recoverable by alkaline flooding processes[32]. This could conceivably be doubled by the use of appropriate surfactant and polymer additives. Several reservoirs were identified as potential candidates, including: David Lloydminster and Wainwright Sparky in east central Alberta, Countess Mannville in southern Alberta, and

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