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Laboratory Experimental Results of Huff 'n' Puff CO_2 Flooding in a Fractured Core System

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Abstract

In this study, the performance and efficiency of CO_2 huff-and-puff process for improving oil recovery and subsequent storage of CO_2 in fractured porous media is examined and the results of laboratory tests are presented. The experimental set up consisted of a high-pressure stainless steel cell made specially to hold a cylindrical core with spacing around it to simulate fractures surrounding matrix. The matrix was saturated with normal decane, which was used as oil during these experiments. Over six sets of huff-and-puff experiments, using CO_2 as solvent, were conducted for pressures of 250, 500, 750, 1000, 1250, and 1500 psi. Each set of the huff-and-puff experiments were conducted by injecting CO_2 in the fracture surrounding the core (injection step). Then, the system was shut-in for a period of 24 hours to allow CO_2 to diffuse from fracture into the oil in matrix (soaking period step). At the end of soaking period, the pressure was released and the oil production was measured (production step). The above cycle was repeated until no more oil was produced. The results obtained showed that CO_2 huff-and-puff process improves the oil production from fractured media, significantly. These results also indicate that the oil recovery is higher for huff-and-puff experiments conducted at higher pressures.

Introduction

Application of Huff-and-Puff process has been tested as a means of implementing variety of enhanced oil recovery processes, such as CO_2 and hydrocarbon solvent injection in conventional oil reservoirs. Huff-and-puff process improves oil recovery through oil swelling, hydrocarbon extraction, viscosity reduction and relative permeability effects (Monger and Coma, 1988, Haskin and Alston, 1989). Since such a technique is applicable through single well, it is also recognized as relatively low initial capital outlay and rapid payout (Haines and Monger, 1990). Many studies on applicability of huff-and-puff process have been conducted through utilizing various miscible and immiscible solvents for improving oil recovery from oil reservoirs (Heines, 1990; Lino, 1994; Johnston, et al., 1990). While, sequential steam huff-and-puff technique can increase the oil recovery from heavy oil reservoirs significantly (Shuhong, et al., 2005), cyclic CO_2 injection has been proposed as an alternative to cyclic steam stimulation for heavy oil reservoirs. However, it is found that CO_2 huff-and-puff process has wider applications in light–oil reservoirs (Thomas and Monger, 1990). An early application of immiscible cyclic CO_2 injection process was reported by (Gondiken, 1988) through a pilot project carried out by Turkish Petroleum Corporation in Camurla Field that has a heavy crude oil of 11-12 ^{o}API. The results of this early application of huff-and-puff immiscible CO_2 project were not economical in all stages due to the lack of equipment and some field problems. However, significant reduction in the oil viscosity and interfacial tension resulted in improving oil recovery in some stages of this project. Also, there was an evidence of dissolution of calcium carbonate by carbonic acid, which resulted in improved permeability. Another study by Monger and Coma (1986) showed that post waterflood residual oil could be displaced by CO_2 huff-and-puff process in a light crude oil Berea core. According to their studies, operating at minimum miscibility pressure (MMP) is not beneficial and process is not sensitive to duration of soak period. However, they suggested additional investigations on the effect of reservoir and operating pressure on the efficiency of huff-and-puff process. Later on, Haskin and Alston (1989) evaluated CO_2 huff-and-puff tests in 12 fields in east and south of Texas. They confirmed that soak times of 2 to 3 weeks result the same oil recovery as longer soak periods. However, both laboratory study by Monger and Coma (1988) and limited field data analysis by Haskin and Alston (1986) show that oil recovery can be improved by increasing the amount of CO_2 injected. During immiscible CO_2 cyclic injection, it has been seen that ultimate oil recovery is largely dependent on oil saturation. Since solubility of CO_2 is a function of pressure, at conditions below MMP a small amount of CO_2 is dissolved in the oil. Hence, in order to have better ultimate oil recovery CO_2 must contact a large amount of oil and initial oil saturation has significant impact on the efficiency of the process (Miller, 1990). Formation and