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A study of the mechanism of enhancing oil recovery using supercritical carbon dioxide microemulsions

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Abstract: Supercritical carbon dioxide ($scCO_2$) microemulsion was formed by supercritical CO_2, H_2O, sodium bis(2-ethylhexyl) sulfosuccinate (AOT, surfactant) and C_2H_5OH (co-surfactant) under pressures higher than 8 MPa at 45 ºC. The fundamental characteristics of the $scCO_2$ microemulsion and the minimum miscibility pressure (MMP) with Daqing oil were investigated with a high-pressure falling sphere viscometer, a high-pressure interfacial tension meter, a PVT cell and a slim tube test. The mechanism of the $scCO_2$ microemulsion for enhancing oil recovery is discussed. The results showed that the viscosity and density of the $scCO_2$ microemulsion were higher than those of the $scCO_2$ fluid at the same pressure and temperature. The results of interfacial tension and slim tube tests indicated that the MMP of the $scCO_2$ microemulsion and crude oil was lower than that of the $scCO_2$ and crude oil at 45 ºC. It is the combined action of viscosity, density and MMP which made the oil recovery efficiency of the $scCO_2$ microemulsion higher than that of the $scCO_2$ fluid.

Key words: Supercritical carbon dioxide, microemulsion, MMP, enhancing oil recovery

1 Introduction

Supercritical CO_2 ($scCO_2$) is one of the environmentally friendly and nontoxic fluids. It has been widely used for many industry processes because of its low critical temperature, moderate critical pressure and low price (Eckert et al, 1996; Yu et al, 2006; Chattopadhyay and Gupta, 2001; Kalogiannis et al, 2005; Kikic et al, 1997; Matson et al, 1987; Zhao et al, 2011).

To realize a win-win situation of enhancing oil recovery and CO_2 emission reduction, injection of released CO_2 into reservoirs is becoming an important way of beneficial CO_2 utilization (Shen and Yang, 2006; Roper et al, 1992; Grigg and Siagian, 1998; Christensen et al, 1998; Langston et al, 2003). There are two types of CO_2 flooding: miscible flooding and immiscible flooding. For miscible flooding, there is a stable flooding zone formed, and the microscopic displacement efficiency is higher than 90%. Meanwhile for immiscible flooding, the displacement efficiency is low. Most reservoirs in China are continental depositional ones; the minimum miscibility pressure (MMP) for CO_2 flooding is higher than the formation fracture pressure, so miscible flooding cannot be achieved, which results in a low displacement efficiency. If the MMP may be controlled lower than the formation fracture pressure, CO_2 would be miscible with crude oil, and then the displacement efficiency would be significantly improved.

Nowadays, the commonly-used method to decrease MMP is to add hydrocarbon gases into the CO_2 (Bon and Sarma, 2005; Yuan et al, 2004). However, this method is difficult to apply in the reservoirs with few hydrocarbon gases. Moreover, the hydrocarbon gases injected into the reservoir may separate from CO_2, which makes the MMP of CO_2 flooding increase. This means that the miscible flooding cannot be achieved.

The $scCO_2$ reverse microemulsion method is a combination of supercritical technology and microemulsion technology (Liu et al, 2001; Luo et al, 2005; Zielinski et al, 1997; Zhang et al, 2009; Hutton et al, 1999; Heitz et al, 1997; Eastoe et al, 1996). Surfactant molecules are dissolved in the $scCO_2$ fluid, spontaneously forming nanoscale aggregates in the $scCO_2$ microemulsion is widely used in many industrial processes, such as chemical reaction, extraction and synthesis of nano-particles (Sun et al, 2001; Holmes et al, 1999; Kane et al, 2000; Ohde et al, 2005), but there is no reports about using $scCO_2$ microemulsion for enhancing oil recovery.

For the microemulsion system, $scCO_2$ is the continuous phase and the surfactant molecules are dissolved in the $scCO_2$ fluid which makes it is possible for the microemulsion

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