Effect of CO_2-Oil Contact Time on the Swelling Factor and Viscosity of Paraffinic Oil at Reservoir Temperature

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Abstract

The objective of this experimental study is to investigate the effect of CO_2-oil contact time to oil swelling factor and viscosity. A sample from the central Sumatra basin was utilized in this study, which is categorized into paraffinic oil. The experiment condition follows the reservoir condition, which has a low fracture pressure. Thus, miscible injection scheme is impossible to apply. Therefore, the role of CO_2 in reducing oil viscosity and oil swelling is emphasized. The experiments were performed under reservoir temperature by using PVT cell, syringe pump, and HPHT Rheometer. The result from the experiments clearly indicates that oil swelling and viscosity reduction mechanisms are quite effective during 24 h of CO_2 injection. Optimum condition is obtained for the sample with 10 h of CO_2-oil contact-time, where the swelling factor and viscosity reduction still show significant values.

Keywords

CO_2 • Paraffinic oil • Swelling factor • Viscosity • Contact time

1 Introduction

One of the oil fields, located in the central Sumatra basin, has been producing paraffinic crude oil for more than a decade. This oil field is surrounded by an industrial site which has the potential to emit CO_2 gas into the atmosphere. Due to environmental reasons, the emission of CO_2 into the atmosphere could be minimized by injecting the gas (CO_2) into the oil field to enhance recovery. This project will be beneficial in both environmental and financial aspects, since CO_2 gas injection can increase oil recovery [1] and reduce Green House Gas (GHG) emission through subsurface storage [2].

The injection strategy will follow an immiscible injection scheme due to the shallow depth of the reservoir (1200 ft.) and to the low reservoir pressure (approximately 500 psi), which makes it impossible to use in its miscible condition. Oil swelling [3] and viscosity reduction [4] are two mechanisms which are dominant in this injection strategy. Although these two mechanisms yield an incremental level of oil recovery, an optimum time for CO_2 to dissolve inside the crude oil should be reconsidered. This is due to the longer time for crude oil contact with CO_2, the potential of more CO_2 solute inside the crude becomes higher, resulting in a high swelling factor and lower oil viscosity. Therefore, through this experimental study, we will investigate the effect of CO_2-oil contact time on the swelling factor and viscosity. Furthermore, an optimum contact time for oil and CO_2 will be determined based on a point above which an insignificant incremental of swelling factor and decremental of oil viscosity is given.

2 Methodology

The crude oil sample that is utilized in this study is categorized as paraffinic crude oil, which is reflected from higher cloud point. Moreover, the API gravity and viscosity of the

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Table 1 Physical properties of crude oil

Parameter	Value	Unit
Oil gravity	30.8	API degree
Viscosity	17	Cp
Pour point	105–110	F
Bubble point pressure	113	Psi
Wax content	32.93	wt%
Asphaltene content	12.74	wt%

sample in reservoir temperature (136 °F) are 30.8 and 17 cp, respectively (Table 1). The hydrocarbon composition contains more than 95 wt% of hydrocarbon with a carbon number more than six. The swelling factor of the sample is obtained from the swelling test experiment using Stainless steel visual PVT cells. On the other hand, measurement of viscosity is performed by using high-pressure high-temperature (HPHT) rheometer. Each apparatus is equipped with a syringe pump from ISCO company and fully filled with liquid CO_2.

The procedure for determining the swelling factor was initiated with preparation of a 3 ml sample inside the PVT cell and initial height of the sample column was recorded. The PVT cell was then located inside the air bath, where its temperature was constantly maintained at reservoir condition. The tubing line end was connected to the PVT cell while the other was connected to a valve in the syringe pump. All connections were checked to detect the presence of any leakage. After the equilibrium temperature between cell and bath was achieved, the pump pressure was adjusted at a certain injection pressure [in this case, the observation pressure was 900 psi, which is below the fracture pressure (1000 psi)]. CO_2 was injected at constant injection pressure by opening the valve which connects the pump and the PVT cell. The column height of the sample was recorded and measured every hour during 24 h of injection time. The swelling factor was calculated by dividing height during injection with sample initial height.

In the measurement of oil viscosity experiment, the procedure was began by placing an 11 ml sample inside the rheometer cup, then, the cup was installed on the rheometer head in HPHT rheometer apparatus. A complete isolation of the annulus between rotor (cup) and stator (bob or spindle) must be confirmed. The rheometer head with the installed cup was lowered into the thermo-bath and the bath and sample temperature was increased up to reservoir condition, through temperature adjustment at the PC dashboard. The liquid CO_2 pressure was increased to 900 psi and set at constant pressure injection, while awaiting the equilibrium condition of the sample temperature. Liquid CO_2 was injected into the sample cup by opening the valve and the pressure inside became stable at 900 psi after 5 h. Oil viscosity was obtain and recorded at 255 s^{-1} sheer rates for every 5 h during 24 h of contact time.

3 Results

Results from the swelling factor and viscosity experiments are plotted against contact time (in hour unit) in Figs. 1 and 2, respectively. The sample volume swells up to 6% incremental when CO_2 is injected at 900 psi for 24 h. Viscosity plot versus contact time reveals a larger reduction of sample viscosity when the sample comes into contact with CO_2 for a longer period of time. During 24 h of CO_2-oil

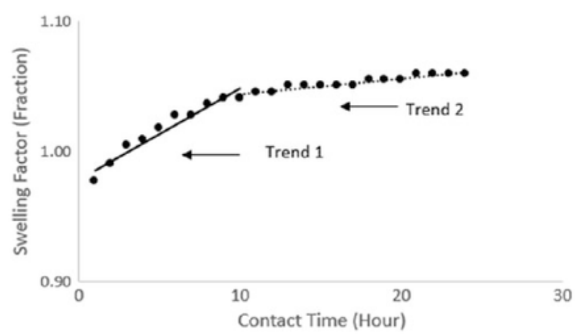

Fig. 1 Swelling factor versus contact time

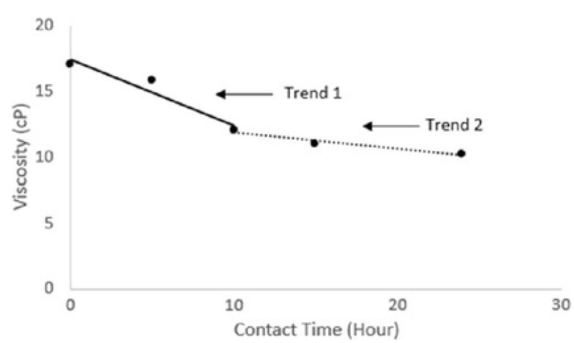

Fig. 2 Viscosity versus contact time

contact time with 900 psi injection pressure, the oil viscosity was successfully reduced from 17 cp down to 10.2 cp, i.e. a nearly 40% reduction from its initial value.

4 Discussion

The plotted results in Figs. 1 and 2, clearly indicate that the oil swelling and viscosity reduction mechanisms, as reported by Al-abri and Amin [3] and Li et al. [4], occur during CO_2 injection into paraffinic oil. Compared to aromatic oil, the swelling factor value of paraffinic oil is relatively lower due to the more tightly bonded carbon chain or higher carbon number. Results from both experiments have shown two trends of data. The first trend ("Trend 1") shows a significant change of value compared to the second trend ("Trend 2"). Based on observation on Fig. 1, "Trend 2" has a lower incremental of swelling factor (0.12%), compared to "Trend 1" (0.7%). Moreover, the decline rate of oil viscosity for the second trend (Fig. 2) is lower (12.5%) than the first trend (50%). There is an insignificant change in the value of viscosity and swelling factor, after 10 h of elapsed time. This might have occured because of CO_2 solubility in the oil at this particular pressure was nearly reached and, thus, the CO_2 dissolution process in the oil was almost completed, which was inspired from the works of Or et al. [5]. Therefore, 10 h is concluded to be the optimum time for CO_2 contact with paraffinic crude oil under 900 psi and 136 °F condition. Moreover, the effect of oil and viscosity reduction to oil recovery, will be investigated in the future. In addition, the collaboration with other experts such as geologists and mechanical engineers is required to understand the subsurface structure and the CO_2 separation process from the environment in order to launch a massive project in the future.

5 Conclusions

Two experimental studies have been performed to investigate the effect of CO_2-crude oil contact time to the oil swelling factor and viscosity. Paraffinic oil from central Sumatra Basin oil field was utilized in two different tests, for obtaining swelling factor and oil viscosity values. Results from the two tests reveal that the oil continuously swells and the viscosity tends to decrease when the CO_2-oil contact time is increased. Optimum condition of CO_2-oil contact time is attained after 10 h, beyond that the results become insignificant in oil swelling factor and low viscosity decline rate.

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