

Minimum Miscible Pressure on the CO₂ Impurities



Dinda Asmara and Riri Permata Sari

Abstract Enhanced Oil Recovery is a method to increase oil recovery from 30% till 60% depend on primary and secondary recovery. One of the proven EOR method to increase oil recovery is CO₂ injection. This injection has 2 conditions: miscible and immiscible. In this research, the purpose of MMP determination is to know the effect of temperature, pure and impurities CO₂ (methane, ethane, propane and H₂S). Simulator is used to determine of MMP. The result is the increase in temperature will increase the MMP. The influence of pure and impure from CO₂ with 80% CO₂ + 20% non CO₂ (C₁, C₂, C₃) components. With CO₂ 100% as reference, the additions of 20% methane will increase 86% MMP, 20% ethane will decrease 13% MMP and for 20% propane will decrease 33% MMP.

Keywords Minimum miscible pressure · Impurities · Temperature

Introduction

Enhanced oil recovery (EOR) is implementation of various techniques to increase the amount of crude oil that can be the extraction from reservoir. EOR also called the increasing of oil recovery factor or tertiary recovery. By using EOR, oil recovery in reservoir can be extraction 30% till 60% depend on primary and secondary recovery. One of the EOR method is CO₂ injection. It is method can increase the recovery factor. CO₂ EOR has been proven in The Hansford Marmaton Field (Flanders et al. 1990).

CO₂ injection has 2 conditions: miscible and immiscible. From those conditions, recovery factor using miscible condition is greater than immiscible condition. Because it make crude oil volume is swollen, viscosity is decreased, interfacial tension is reduced, crude oil driven by solution gas, and light components are extracted to the injected CO₂ phase (Ghedan 2009). To achieve the condition, need

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to know the Minimum Miscibility Pressure (MMP). MMP is minimum pressure for CO₂ miscibility with crude oil.

However, although the recovery factor for miscible condition is greater. Keep attention with the reservoir condition, like pressure reservoir and fracture pressure to prevent fracture or CO₂ injected can deep penetrate reservoir and not dissolve yet. Because of greater MMP value, injection pressure must be greater than MMP.

Because of that, it is important to attention the result of MMP according to reservoir condition by mixing the CO₂ that will be injected with another natural gas such as, methane, ethane and others. So, in this paper the writer try to calculate MMP by pure gas injection, and mixing the CO₂ with various component such as methane, ethane, propane, sulfur (impure), and CO₂ with flare gas by using Compositional simulator (Computer Modeling Group 2009).

Determination of Mmp

Determination of MMP has some methods, such as rising bubble technique, vanishing interfacial tension test and others. But, there are 4 primary methods that have been used in recent years to determine MMP for specific fluid displacement are: slim tube experiments, compositional simulation (Rathmell et al. 1971), mixing cell models and analytical methods.

Slimtube Experiments

Slimtube measurement is one of the standard experimental techniques that used for determining the Minimum Miscibility Pressure (MMP) of an oil and injection gas before initiation of Enhanced oil recovery (EOR) projects. Slimtube is a cylinder tube with a diameter of 0.25 in. with length ranging from 25 to 75 ft. The tube is initially saturated with the reservoir oil above is bubble point pressure. Then, the oil is then displaced by the gas injection from the tube at a fixed experimental pressure controlled by a back pressure regulator. Miscibility conditions are determined by conducting the experiment at a various pressures and recording the oil recovery. Then, MMP can be predicting with plotted curve oil recovery with pressure (Amao et al. 2012).

Mixing Cell Methods

The basic idea in this multiple mixing cell is to mix gas and oil in repeated contacts, resulting in new equilibrium compositions. This Mixing cell methods can give reliable MMP for either Condensing (enriched gas injection) or Vaporizing (lean

gas injection). In case of the vaporizing drive, the intermediate component in oil is vaporized into the more mobile gas phase, and miscibility is developed when the equilibrium gas is repeatedly mixed with oil, causing the equilibrium gas composition to move toward the oil tie line. Thus, in vaporizing drive the tie line that extends through the oil control the development of miscibility. For condensing drive, the intermediate component gas is condensed into oil, and the gas tie line controls miscibility (Ahmadi and Johns 2008).

Analytical Methods

Analytical method (MOC) are based on methods of characteristic (Amao et al. 2012), or analytical method are based on the analytical solution of dispersion free 1D flow equation. MOC depend of finding the key tie lines. This key tie line are found such that key tie line when extended out of two phase region must intersect two neighboring key tie lines. As pressure is increase the key tie line are determined until one of them first intersects a critical point. MMP is the pressure at which the first key tie line become zero length (Ahmadi and Johns 2008).

Correlation

Correlations are often used to estimate MMP that the injected fluid is pure or impure. There are many correlations that can be used for calculate MMP such as Yellig and Metcalf, Helm and Josendal, Cronquist, and Glaso correlation. Glaso correlation for pure CO₂ injection is more accurate (Yuan 2004).

In this paper, the writer use Glaso correlation with if percent mol C₂₋₆ > 18% with equation,

$$MMP_{Pure} = 810 - 3.404M_{C7+} + 1.700 \times 10^{-9} M_{C7+}^{3.730} e^{786.8M_{C7+}^{-1.058}} \times T \quad (1)$$

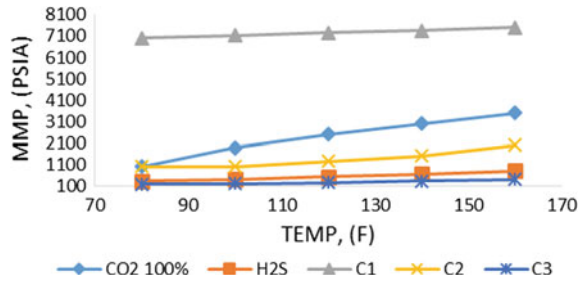
And for C₂₋₆ < 18%,

$$MMP_{Pure} = 2947.9 - 3.404M_{C7+} + 1.700 \times 10^{-9} M_{C7+}^{3.730} e^{786.8M_{C7+}^{-1.058}} \times T - 121.2C_{2-6} \quad (2)$$

where T is reservoir temperature, M_{C7+} is the molecular weight of C₇₊.

The purpose of using correlation is to know the different MMP between simulator with glaso correlation. From Eq. (1), MMP value is 5869 psia, whereas with simulator is 5125 psia, so percent error from glaso correlation and simulator is 12.67%.

Fig. 1 Comparison of MMP values at 100% natural gas



Result and Discussion

Compositional simulator is used to determine MMP. This determination is to know MMP with pure injection gas and combining. MMP is depending by temperature, oil composition, pure and impure gas injection. (Yellig and Metcalfe 1982; Alston et al. 1982; Sebastian et al. 1985) Where the oil composition (Al-Qasim et al. 2017) as the dependent variable, while the composition of gas injection and temperature as the independent variable.

In Fig. 1 can be seen the MMP value influenced by temperature. MMP for CO₂ increase with temperature and suggest that this occur, it take a higher pressure to achieve the same CO₂ density at a higher temperature. (Karimale 2010) By doing injection 100% on each component (CO₂, Methane, Ethane, H₂S, and Propane). To see how the ability on each component and know the influenced from increasing temperature with minimum miscibility pressure. So the result is the increase in temperature will increase the MMP value. Sequentially the MMP value from greater till smaller are Methane, CO₂, Ethane, H₂S, and Propane.

C₁ 100% injection has a greater MMP value than CO₂ 100%. Because of, the density from methane is small so, requires the big pressure to dissolve methane in fluid. It made C₁ injection can improve the oil recovery, but CO₂ injection is a very efficient to recovery method. (Holm 1982) While, component intermediate and H₂S has a smaller MMP value. However, that gas injection can't used 100% to reach target of MMP, because of being attention with reservoir condition and also about cost. To achieve the MMP value, the necessity of mixing the CO₂ with another natural gas.

So, to know the influenced of pure and impure from CO₂ is in Fig. 2. Where in the same of temperature with 80% CO₂ + 20% non CO₂ (C₁, C₂, C₃) components. With CO₂ 100% as reference, the additions of 20% methane will increase 86% MMP, 20% ethane will decrease 13% MMP and for 20% propane will decrease 33% MMP.

From the result above, the effect of CO₂ impurities component on the CO₂ minimum miscible pressure at the same temperature, whereas C₁ higher negative impact on the MMP, because the component increase the CO₂ MMP. But H₂S and intermediate component (C₂ and C₃) have positive impact on the MMP. It have been reported (Shokir and Eissa 2007).

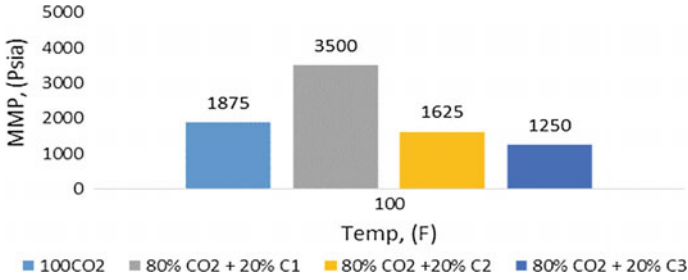


Fig. 2 Comparison of MMP 100% CO₂ versus 80% CO₂ + 20% non CO₂

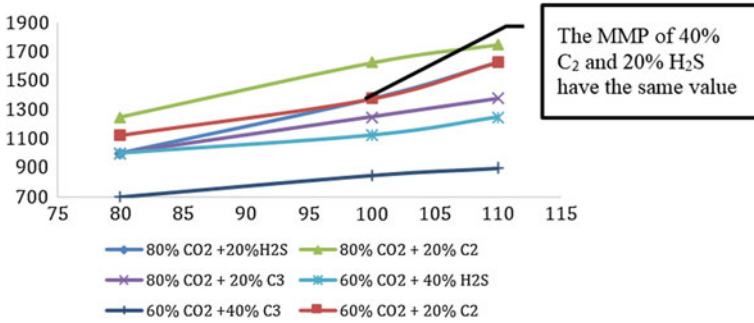
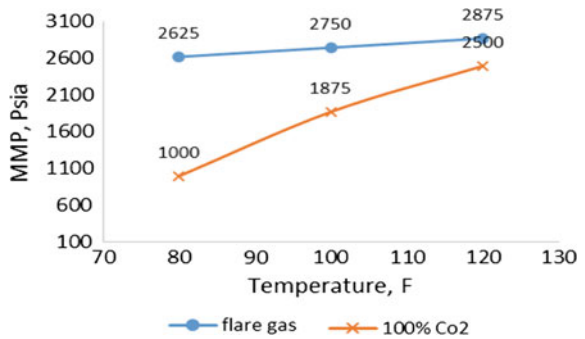


Fig. 3 Comparison of MMP with the addition intermediate component and H₂S

Fig. 4 Comparison of MMP 100% CO₂ versus Flare Gas



Because H₂S is a dangerous gas. So, In this research also show that the use of H₂S can be replaced by using C₂ with ratio 1:2 and Will be achieve the same of MMP at the same temperature (Fig. 3).

As a comparison materials, we also present flare gas data. With the purpose to compare the MMP flare gas with MMP CO₂ 100%. Can be seen in the graph below, CO₂ 100% has a lower MMP than MMP flare gas. Because of the flare gas composition contains more methane (Fig. 4).

Conclusions

The main conclusion from this research are as follow:

- Temperature influence The MMP.
- The effect of mixing the CO₂ (impurities) with natural gas such as methane, ethane is helpful in achieving of MMP according to reservoir condition.
- The influence of component methane will increase MMP, While Component intermediate will decrease MMP.

Acknowledgements We would like to thank Department of Petroleum Engineering, Universitas Islam Riau and Dr. Eng. Muslim for the support in writing this paper.

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