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Investigating the Performance of Generalized Fick and Maxwell-Stefan Molecular Diffusion Models for Simulation of Oil Recovery from Fractured Reservoirs during CO_2 and Methane Gas Injection Processes

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Introduction

Molecular diffusion is the controlling mechanism for oil recovery from fractured reservoirs with low permeable and low height matrixes during gas injection process [1]. Although there are a lot of studies in gravity drainage area, molecular diffusion is rarely discussed in literature [2]. Molecular diffusion can be expressed by three different models which are Classical Fick model, Maxwell-Stefan model, and Generalized Fick model. The main purpose of this study is to investigate the performance of different diffusion molecular models for oil recovery from fractured reservoirs during gas injection process and compare the results with a commercial simulator. While application of conventional models for simulation of molecular diffusion process faces some limitations, commercial simulators often use them [3]. In this study, it will be shown that Maxwell-Stefan model and Generalized Fick model when coupled with irreversible thermodynamic method are more acceptable although more complicated [4,5]. The novelty of this work is forming a model which eliminate the other mechanisms of oil recovery and focus on molecular diffusion. In addition, a multi component fluid from a real reservoir is chosen to have an actual analysis on this issue. Furthermore, a comparison between the results of CO_2 and methane injection in the different molecular diffusion methods will be presented.

Methodology

In this study, a simulator has been developed to investigate the performance of different models of molecular diffusion and compare with the commercial simulator results. At first, different models are implemented as a simulator based on the formulation which exists in literature [6,7]. Then, the prepared simulator is validated by experimental data. Lastly, the developed simulator is applied for evaluation of CO_2 and methane injection in one matrix block. Therefore, the effect of molecular diffusion on oil recovery can be detected.

The simulator has been verified by valid experimental data. N_2 and liquid hexane were contacted in an appropriate cell [8]. The concentration of N_2 in liquid hexane was measured after 16 days. This concentration was related to diffusivity of N_2 in liquid hexane. As shown in Figure 1, the results of the developed simulator can be adjusted with experimental data.

An appropriate model is needed to investigate the different methods of molecular diffusion. This model is shown in Figure 2. The oil composition is based on a sample from an Iranian reservoir. A 1000 m3 matrix block is chosen to represent a reservoir block. This block surrounded by fracture. The injected gas diffuse from fracture area and oil will be produced from the center of matrix block. The pressure will be constant in the procedure. Therefore, the total oil recovery will be related to the diffusivity of gas in oil.

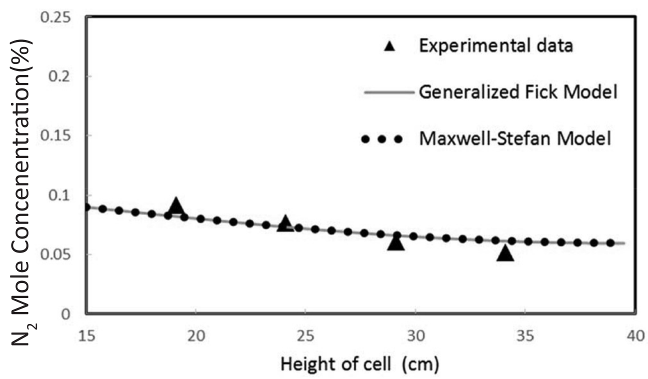

Figure 1: N_2 mole concentration in liquid hexane after 16 days contact.

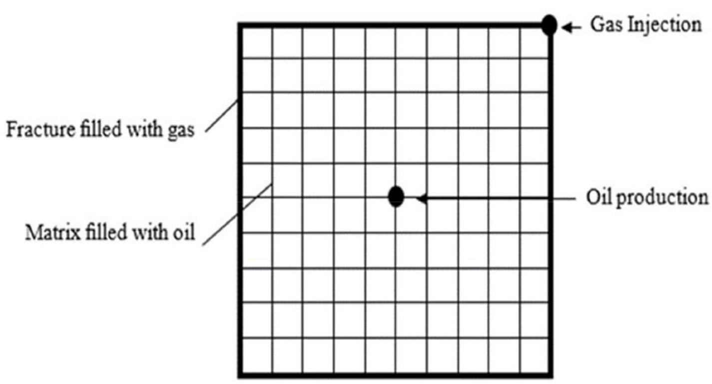

Figure 2: Applied model for molecular diffusion simulation.

Results and Discussion

Oil recovery during methane injection

As shown in Figure 3, methane mole fraction in oil composition would increase during methane injection process which means that methane would diffuse in oil. As a result, oil would be produced via molecular diffusion mechanism. It has been shown that Generalized Fick model and Maxwell-Stefan model demonstrate same results because of same formulation. However, classical Fick model and Eclipse300 show different results which express the limitation in their formulation. Although Generalized Fick and Maxwell-Stefan Models are more complicated in formulating and applying, they are more reasonable. The comparison between the oil recoveries of different molecular diffusion models has been shown in Figure 4. It is important to note that choosing valid diffusion model can have significant effect on the result of simulation in fracture reservoirs.

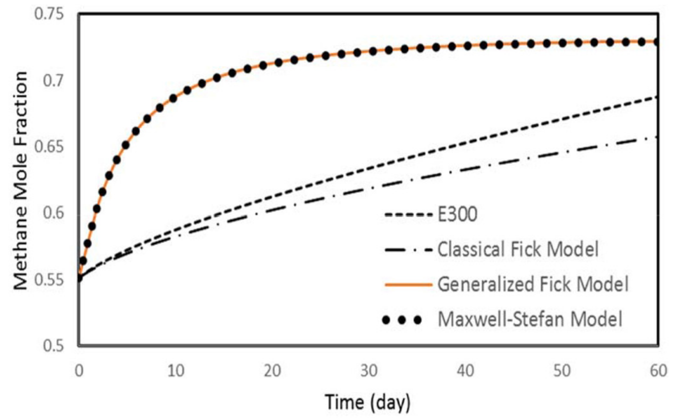

Figure 3: Methane mole fraction in oil during methane injection in matrix.

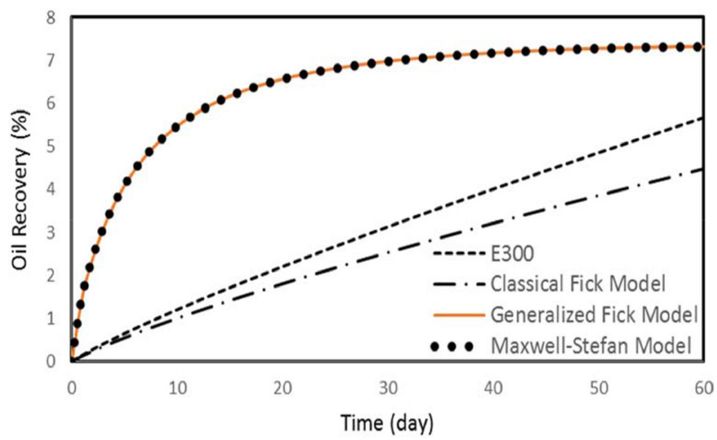

Figure 4: Oil recovery via molecular diffusion mechanism during methane injection.

Oil recovery during CO_2 injection

In any case, CO_2 miscible injection would be more efficient in oil recovery than methane injection. In so doing, CO_2 mole fraction in oil and the oil recovery via CO_2 injection have been shown in Figures 5 and 6. Likewise, the results of commercial simulator and classical Fick model are almost similar. However, a fundamental difference can be seen between the results of them and generalized Fick model.

In terms of oil recovery, CO_2 injection is more efficient than methane injection as CO_2 causes heavy components rapidly produced from the matrix block. It has been shown in Figure 7.

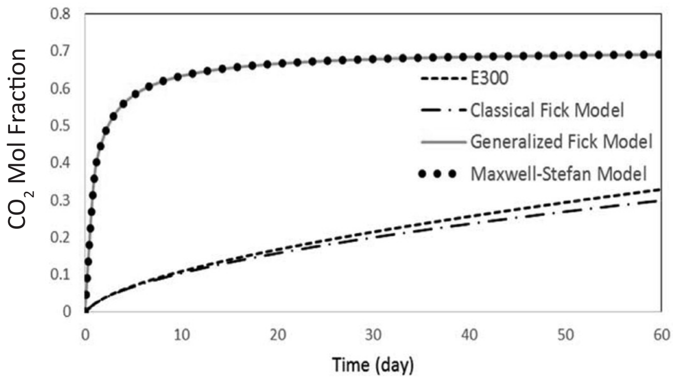

Figure 5: CO_2 mole fraction in oil during CO_2 injection in matrix.

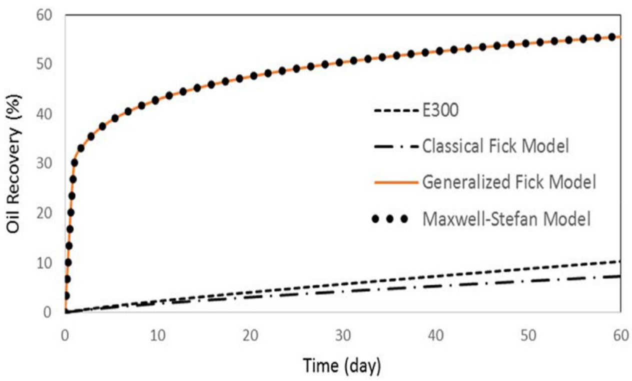

Figure 6: Oil recovery via molecular diffusion mechanism during CO_2 injection

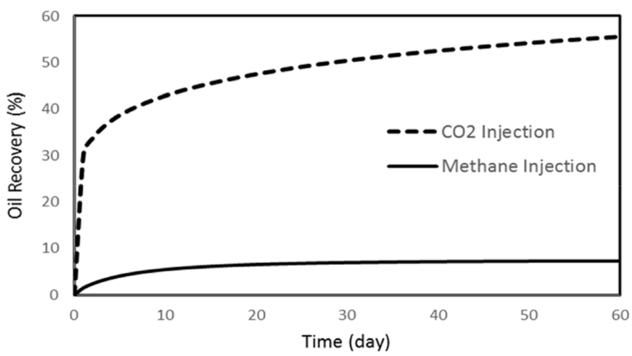

Figure 7: Oil recovery during methane and CO_2 injection formulated by Generalized Fick model.

Conclusions

In this article, the performance of different diffusion molecular models for oil recovery from fractured reservoirs during gas injection process was investigated and compared with commercial simulator results. For this purpose, the developed simulator which was validated by experimental data was applied for evaluation of CO_2 and methane injection in one matrix block. It has been shown that the difference between the results of different models is based on using irreversible thermodynamic for calculating component concentration in gas-oil interface, using matrix form of molecular diffusion coefficients and using chemical potential gradient as the driving force in generalized Fick and Maxwell-Stefan verse classical Fick. In addition, the results of commercial simulator are near classical Fick model results because of same formulation. The result of this work demonstrates that using classical Fick's law or the commercial simulator for forecasting oil recovery from fractured reservoirs when the molecular diffusion is the main mechanism is not accurate so generalized Fick and Maxwell-Stefan are more efficient models.

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