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Neural Network Models for Predicting the Size and Horizontal Location of Shale Barrier Using Reservoir Parameters and SAGD Production Data

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Summary

The modelling of an interbedded shale barrier in heterogeneous oil sands reservoirs has high uncertainty, which has a critical impact on the steam-assisted gravity drainage (SAGD) performance. Generally, an interpretation of 4D seismic data is the most widely used method for understanding the uncertainty of the shale barrier size. However, the 4D seismic data interpretation incurs additional cost during long term operation. In this study, the neural network models were developed to predict the size and horizontal location of shale barrier using reservoir parameters and the SAGD production data without utilizing a 4D seismic data interpretation. The R^2 results showed that the neural network model for predicting width (0.85) and length (0.93) of shale barrier are high, while the horizontal location neural network model is as low as 0.65. This neural network model would be very helpful for evaluating the uncertainty of the size and horizontal location of shale barrier, updating the existing static reservoir model, and optimizing the recovery processes by incorporating observation well data as well as 4 D seismic data interpretation.

Introduction

The steam-assisted gravity drainage (SAGD) process, was first development by Roger Butler, has been used for one of the most promising in-situ recovery methods to produce oil sands (Butler et al., 1981). The SAGD performance is affected significantly by the low permeability layers and flow barriers, such as the shale barrier depending on their width, length, and vertical location in heterogeneous oil sands reservoirs because it tends to interrupt the development of steam chambers (Shin and Choe, 2009).

The thickness and vertical location of a shale barrier can be defined from the well-logging data, but the uncertainty of its size and location exists in a shale interbedded oil sands reservoir, as shown in Fig. 1. Generally, the interpretation of the 4D seismic data is the most widely used method for understanding the uncertainty of the shale barrier size. However, the 4D seismic data interpretation incurs additional cost during long term operation to monitor steam chamber development. Therefore, it is necessary to develop methods to predict the shale barrier size and location without utilizing 4D seismic data interpretations. Kim and Shin (2018) performed a statistical approach to predict the shale barrier size using the reservoir parameters and the SAGD production data without using 4D seismic data interpretation, but the horizontal location of shale barrier was not considered.

The aim of this study is to develop the neural network model for predicting the size and horizontal location of shale barrier using the reservoir parameters and the SAGD production data without using 4D seismic data interpretation.

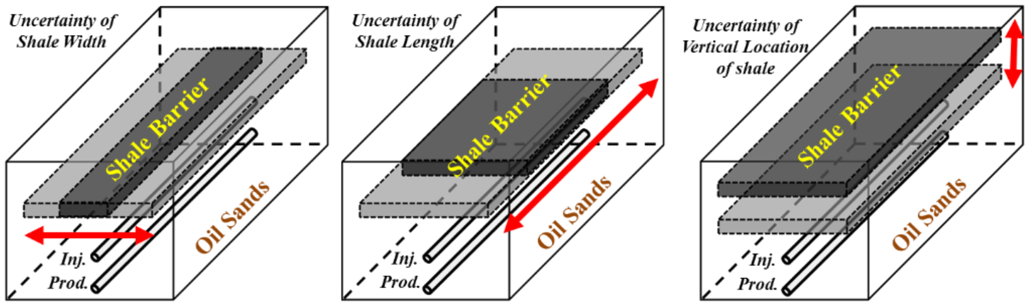

Fig. 1. Uncertainty of the shale size and location such as WD, LN, and VL (Kim and Shin, 2018).

Theory / Method / Workflow

Fig. 2 shows the steam chamber development for both clean and interbedded shale reservoirs, especially, steam in shale interbedded oil sands reservoirs reaches the shale barrier and detours around it. The SAGD production and steam-oil ratio (SOR) curves in shale interbedded oil sands reservoirs are different from those of clean oil sands reservoirs due to the steam detouring at the shale barrier location. In a shale interbedded oil sands reservoir, the SAGD production data such as the oil rate and SOR increase up to a peak point and decreases down to a trough point again, and the points are called inflection points (IP) (Kim and Shin, 2018). As shown in Fig. 3, the characteristics of these IPs are as follows: (1) first production peak (FPP) is the time impeding the development of the steam chamber for the first time; (2) first production trough (FPT) is the time that the steam detours around the shale barrier in the shale width direction for the first time; (3) second production peak (SPP) is the time that the steam chamber is extended to cover the shale barrier except for the center above the shale barrier; (4) MXS is the maximum SOR until the steam is detoured; and (5) MNS is the minimum SOR.

If the width and left location of shale barrier are different and right location of shale barrier is same as shown in Fig. 4, the SAGD production curves before the FPT are the same. Therefore, it is difficult to estimate the horizontal location of shale barrier only using IPs of SAGD production data in the previous study. In this study, we considered the additional production data for 6, 12, 18, 24 months after passing the FPT point.

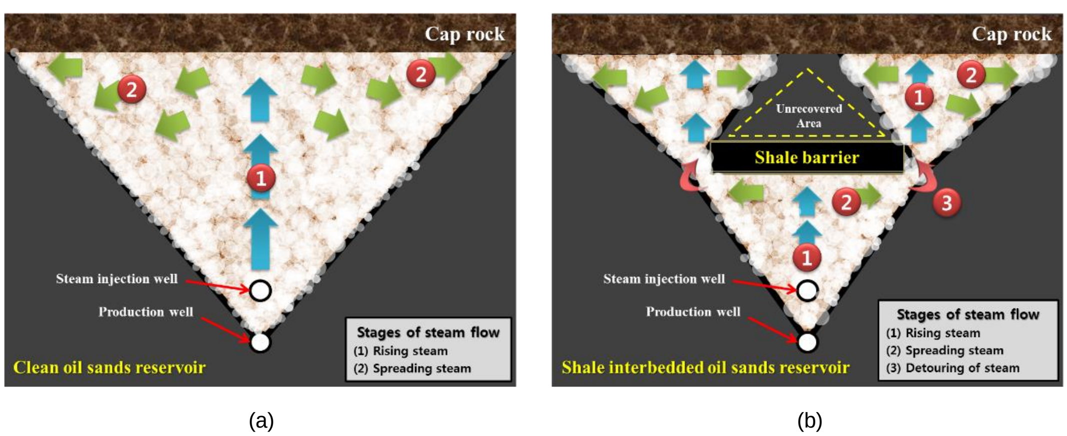

Fig. 2. Development of steam chambers for (a) clean and (b) shale interbedded oil sands reservoirs (Kim and Shin, 2018).

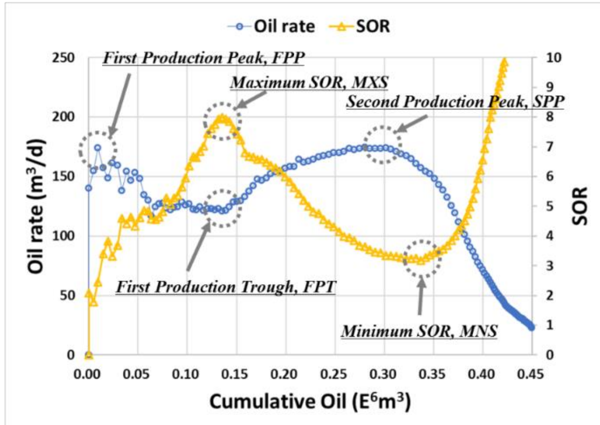

Fig. 3. IPs during the SAGD production in the shale interbedded oil sands reservoir.

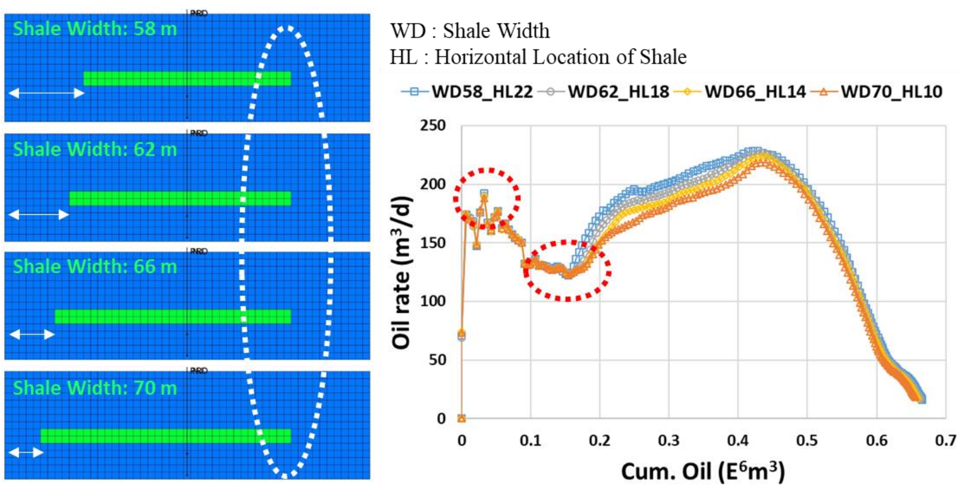

Fig. 4. Comparison of SAGD production curves for various width and horizontal location of shale barrier.

Results, Observations, Conclusions

To develop the neural network models for predicting the width, length, and horizontal location of shale barrier, a Latin hypercube sampling (LHS) was performed using CMG's CMOST to produce 1000 evenly distributed simulation runs. The neural network models are implemented in Python 3.6 using Pandas, Numpy, Tensorflow, and Keras. We use the reservoir parameters, SAGD production data, and thickness and vertical location of shale barrier to train the neural network models for predicting the width, length, and horizontal location of shale barrier. The loss and activation function used in the neural network models are mean absolute error and Relu. The R^2 results showed that the neural network model for predicting width (0.85) and length (0.93) of shale barrier are high, while the horizontal location neural network model is as low as 0.65 (Table 1).

The neural network models would be very helpful for evaluating the uncertainty of the size and horizontal location of shale barrier, updating the existing static reservoir model, and optimizing the recovery processes by incorporating observation well data as well as 4 D seismic data interpretation.

Table 1. Statistical results for the neural network models for predicting the width, length, and horizontal location of shale barrier

Models	Train_loss	Test_loss	Train_R^2	Test_R^2
Shale Width	0.081	0.088	0.85	0.69
Shale Length	0.084	0.086	0.93	0.87
Horizontal Location of Shale	0.120	0.147	0.65	0.25

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