Fuel 231 (2018) 146–156

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

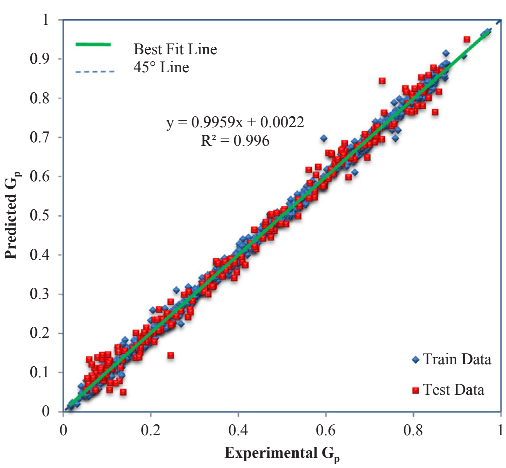
Full Length Article

Reliable modeling of constant volume depletion (CVD) behaviors in gas condensate reservoirs

Adel Najafi-Marghmaleki[a], Afshin Tatar[b,*], Ali Barati-Harooni[a], Milad Arabloo[b], Shahin Rafiee-Taghanaki[a], Amir H. Mohammadi[c,d,*]

[a] Department of Petroleum Engineering, Ahwaz Faculty of Petroleum, Petroleum University of Technology (PUT), Ahwaz, Iran
[b] Young Researchers and Elite Club, North Tehran Branch, Islamic Azad University, Tehran, Iran
[c] Discipline of Chemical Engineering, School of Engineering, University of KwaZulu-Natal, Howard College Campus, Durban 4041, South Africa
[d] Institut de Recherche en Génie Chimique et Pétrolier (IRGCP), Paris Cedex, France

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Gas condensate
CVD test
Model
Neural network
LSSVM
ANFIS

ABSTRACT

It is important to access a clear understanding about the phase behavior of gas condensate reservoirs in order to forecast the future performance of such reservoirs. In this communication, different models based on multilayer perceptron network (MLP NN), least square support vector machine (LSSVM), adaptive neuro inference system (ANFIS) and radial basis function networks optimized by genetic algorithm (GA-RBF NN) were developed for estimation of amount of produced gas using constant volume depletion (CVD) tests of retrograde gas condensate reservoirs. Results show that the developed models are capable of accurately estimating the cumulative produced gas (G_p) as an output parameter by utilizing various input parameters including temperature, pressure, composition of gas, and properties of plus fraction. The analysis of results reveals that the GA-RBF NN presents more accurate results in comparison with MLP NN, ANFIS and LSSVM models. Moreover, comparison between GA-RBF NN model as the most accurate model developed in the present work and two literature models shows

* Corresponding authors at: Discipline of Chemical Engineering, School of Engineering, University of KwaZulu-Natal, Howard College Campus, Durban 4041, South Africa.
E-mail addresses: Afshin.Tatar@gmail.com (A. Tatar), a.h.m@irgcp.fr (A.H. Mohammadi).

https://doi.org/10.1016/j.fuel.2018.04.130
Received 3 May 2016; Received in revised form 26 March 2018; Accepted 25 April 2018

the superiority of GA-RBF NN. Results of this study can be used in PVT softwares to enhance the accuracy and precision of CVD modeling of gas condensate reservoirs.

1. Introduction

Gas condensate reservoirs are gas reservoirs with highly complex performance. This complexity is more related to their flow patterns and thermodynamic behaviors. These reservoirs become more complex when their pressure falls below dew point during production [1,2]. In addition, when the pressure drops down below the dew point the condensate saturation increases and decreases the gas flow. The choking phenomena can decrease the well productivity so much [3,4]. According to these problems it is important to predict and estimate the performance of gas condensate reservoirs during the production stage [5–8]. Lack of enough information about such reservoirs may lead to the decrease in productivity of gas condensate reservoirs and lower the valuable condensate [9,10]. One of the damages that normally occur in gas condensate reservoirs with heaver components in the gas is condensate blockage. Condensate blockage extremely reduces productivity by reducing gas relative permeability. For considering and accounting on the effects of these problems, experimental methods are conventionally applied. Using experimental techniques like measuring dew point and condensate gas ratio is time consuming and expensive and need special equipment to do these tests [5]. In addition, some characterizations of gas condensate reservoirs can be calculated by analytical techniques like behavior relationship and material balance. For example, Olaberinjo et al. [8] used reservoir volumetric balance for estimation of condensate gas ratio in a gas condensate reservoir. Humoud and Al-Marhoun et al. [11] developed a correlation for estimation of amount of dew point pressure. Cho et al. [12] used an equation of state method in their research. Although numerous number of equations of state [13–15] have been developed to model reservoir fluids phase behavior, they may not accurately simulate the phase behaviors of complex hydrocarbons such as gas condensates in the retrograde region [16]. Analytical solution for the reservoir in most cases is a difficult method since a reservoir consists of many components and utilization of analytical methods is time consuming as well as difficult to do. Nowadays, with the aid of computers, artificial intelligence has become an inseparable part of engineering and scientific calculations especially in chemical and petroleum engineering. Zendehboudi et al. [17] used Artificial Neural Network (ANN) to estimate the amount of condensate gas ratio as a function of molecular of weight of gas, pressure, temperature, and dew point pressure. Ghiasi et al. [18] studied on gas phase and two phase deviation factor of gas condensate. They used a soft computing model to estimate the target parameters. Arabloo and Rafiee-Taghanaki [19] used Least Squares Support Vector Machine (LSSVM) method for estimation of amount of produced gas based on experimental Constant Volume Depletion (CVD) tests. They used two models, which were based on polynomial kernel function and RBF kernel function. Their analysis show that the developed model based on kernel function is more accurate and reliable than other models.

Developing general and precise models for modeling the gas recovery in gas condensate reservoirs is of great importance for predicting the future reservoir performance and further required processing. In addition, the thermodynamic models which are used for modeling and prediction of this parameter exhibit some disadvantages and weaknesses including their limitation for generalization of results because these thermodynamic models are suitable in certain domains and are not global models and also the fact that the outcomes of these models are only applicable to the mixture and fluids which they have been developed and designed for. In other words, various tuning and adjustable variables are required for modeling a system with these models which their values should be optimized based on experimental data within limited and restricted range of thermodynamic conditions.

In this study, multilayer perceptron network (MLP NN), least square support vector machine, adaptive neuro inference system (ANFIS) and radial basis function networks optimized by genetic algorithm (GA-RBF NN) were utilized to estimate the cumulative produced gas (G_p) in gas condensate reservoirs. More than 200 samples of laboratory studies on CVD tests (the same data bank as the work of Arabloo and Rafiee-Taghanaki [19]) were used for gas condensate system. Results show that although all developed models in the present work exhibit accurate estimations, the GA-RBF NN model is the most accurate model among them. Comparison between results of GA-RBF NN model as the most accurate model and the model proposed by Arabloo and Rafiee-Taghanaki [19] show the superiority of GA-RBF NN model developed in the current work.

2. Models

2.1. Multilayer perceptron neural network

Artificial neural networks (ANNs) are utilized for modeling the complicated problems. This approach motivates from the behavior of biological neuron to discover the connections between the parameters of a particular issue. ANNs' structure consists of several computational units/neurons. Parallel arrangement and combination of these computational units/neurons, and no requirement of clear and exact formulation and details for the problem are the featured (highlighted) properties of this approach [20]. The computational procedure of these systems comprises of finding the best arrangement of interconnections (weight and biases) between the specified units/neurons to obtain the best execution for the model. Graphical delineation of Multilayer Perceptron (MLP) neural network structure is represented in Fig. 1. This figure shows three sorts of layers incorporated in the basic MLP neural network design, which are input, output, and hidden layers. The input and output layers are in direct contact and connection, while others are interior and invisible layers. Each of these three layers contains large amounts of units/neurons in which the number of units/neurons for hidden layer part must be optimized by intelligent strategies. The relationship between the parameters of problems determines the configuration and arrangement of MLP network's interconnections. MLP's modeling knowledge and capability is stored (prepared) in this obtained unique design of interconnections [21]. The perfect modeling capability of MLP network can be achieved by finding the optimum interconnections configuration using optimization algorithms. In this work, mean square error was selected as a comparison criterion to evaluate the created MLP networks. The iteration number in the

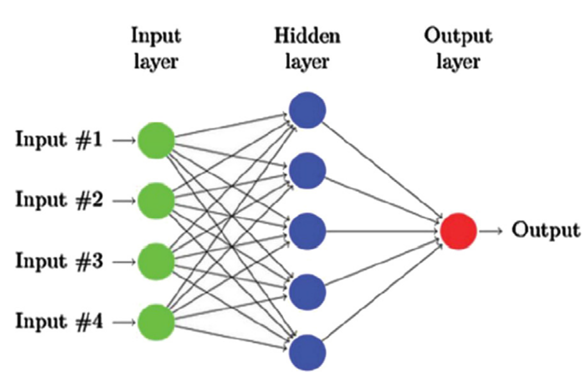


Fig. 1. Structure of an MLP NN [50].