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Comparative evaluation of back-propagation neural network learning algorithms and empirical correlations for prediction of oil PVT properties in Iran oilfields

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ABSTRACT

This paper presents a new approach to improve the performance of neural network method to PVT oil properties prediction. The true value of PVT properties which is determined based on the accurate data is a challenge of the petroleum industry. The main goal of the following investigation would be the performance comparison of various back-propagation learning algorithms in neural network that could be applied for PVT prediction. Up to now, no procedure has been presented to determine the network structure for some complicated cases, therefore; design and production of neural network would be almost dependent on the user's experience. To prevent this problem, neural network based recommended procedure in this study was applied to present the advantages. To show the performance of this procedure, several learning algorithms were investigated for comparison. One of the most common problems in neural network design is the topology and the parameter value accuracy that if those elements selection was correctly and optimally, the designer would achieve better results. Since, fluids of different regions have varying hydrocarbon properties, therefore, the empirical correlations in different hydrocarbon systems should be investigated to find their accuracies and limitations. In this study, an investigation of different empirical correlations along with the artificial neural networks in Iran oilfields has been presented. Then, the new model of artificial neural network for prediction of PVT oil properties in Iran crude oil presented. To test this new method, it was evaluated by collecting dataset from 23 different oilfields in Iran (south, central, western and continental shelf). In this study, two networks for prediction of bubble point pressure values (P_b) and the oil formation volume factor at bubble point (B_{ob}) were designed. The parameters and topology of the optimum neural networks were determined and in order to consider the effect of these networks designing on results, their performances were compared with various empirical correlations. According to comparison between the obtained results, it shows that the improved method presented has better performance rather than empirical and current methods in neural network designing in petroleum applications for these predictions.

1. Introduction

Accurate determination of PVT properties in fluid reservoir such as bubble point pressure (P_b) and oil formation volume factor at bubble point (B_{ob}) for various activities in reservoir and petroleum engineering is very important. However, Pressure–Volume–Temperature (PVT) properties could be obtained by experimental measurements on representative samples of crude oil, but, sometimes because of lack of experimental data, the value of reservoir fluid properties would be necessary. Actual data unavailability may be because of sampling cost, uncertainty of measurements or obtained data, inaccessibility of fluid samples of reservoir hydrocarbon or disability of samples obtaining. As mentioned, the PVT properties such as bubble point pressure (P_b) and oil formation volume factor at bubble point (B_{ob}) for reservoir studies are very necessary. Usually these properties are measured by bottom well samples in PVT cells. Mentioned phase properties are depended on pressure, temperature and fluid chemical composition.

Although the fundamental oil components are limited, but determination of oil properties in absence of actual data, never solved without error through analytical methods and mainly determination of these properties by Equation Of States, empirical correlations or new substituted methods have their own limitations, disadvantages and specific errors. One of the main advantages of the current study rather than the other empirical correlations' based ones are that in this paper we present a method which can be used in different situations with different data. Actually, in this study first we present the ANN as a powerful method for prediction of PVT properties. Then, we present an optimal procedure to find an ANN which can has the best or near the best answer. Next, the performance of ANN rather than the other empirical correlations will be discussed.

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2. Review on previous studies

In Petroleum industry there are lots of highly complex dynamic problems that make high-stakes decisions (Mohaghegh, 2005). Several studies reported successful implementations of the neural network technique for the prediction tasks. For example, Al-Fattah and Startzman (2001) applied neural network for predicting Natural-Gas production. Finol et al. (2002) used this technique for NMR logging data inversion. Weiss et al. (2002) investigated neural network for forecasting oil production. Description of neural network applications in petroleum engineering (Mohaghegh, 2000), intelligent systems application in candidate well selection and treatment of gas storage wells (Mohaghegh et al., 2001) and Prudhoe Bay oil-production optimization (Mohaghegh et al., 2002) are other samples of successful implementations of neural networks in petroleum industry.

The comparative published studies between performance of neural networks and empirical correlations presented excellent performance of designed networks against the empirical correlations. Current investigation is the first attempt to intelligent simulation of PVT behavior on Iran crude oils.

In this paper, various empirical correlations and their limitation would be validated and also, new neural network models according to collected PVT Dataset from different Iran oilfields for prediction of PVT properties would be developed and presented.

2.1. Empirical researches

In recent years, several empirical correlations for PVT properties have been used. These consecutive studies were carried out and corrected prior to correlation development. For example, in 1997, Al-mehaideb (1997) presented a new set of correlations for UAE crude oils, based on 62 data sets that were developed for bubble point pressure and oil formation volume factor. The bubble point pressure correlation uses the oil formation volume factor as input in addition to oil gravity, gas gravity, solution gas oil ratio, and reservoir temperature (like Omar and Todd's (1993) correlation). Also, in 1997, Al-Shammasi (1997) evaluated the published correlations for bubble point pressure and oil formation volume factor. He used global data from 1661 published and 48 unpublished data sets from different geographical locations all over the world, to evaluate the accuracy and flexibility. He presented a new correlation for bubble point pressure and also concluded that statistical and trend performance analysis showed that some of the correlations violate the physical behavior of hydrocarbon fluid properties.

2.2. Artificial neural network studies on PVT properties

As mentioned earlier, several empirical methods were used to predict PVT properties and most of them are based on pervious works and also attempt to obtain new formulation and coefficients which could be applied in different situations. But, artificial neural networks (ANNs) are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the network function is determined largely by the connections between elements. One can train a neural network to solve the problems that other methods could not be able to simulate them and find the spatial relations between their variables. During the latest years, petroleum engineers attempt to use this powerful tool for petroleum applications (Mohaghegh, 2005). Few researchers tried to model PVT properties by ANN. Table 1 presents the quality of recent studies on PVT properties by ANN in several case studies and situations. For example, in 1999, Varotsis et al. (1999) developed a novel approach to predict the complete PVT behavior of reservoir oils and gas condensates, using Artificial Neural Network. The method uses key measurements that can be performed rapidly either in the lab or at the well site as input to an ANN. The ANN was trained by a PVT studies database of over 650 reservoir fluids from the entire world. Tests of the trained ANN architecture utilizing a validation set of PVT studies indicate that, for all fluid types, most PVT property estimates can be obtained with a very low mean relative error of 0.5–2.5%, with no data set having a relative error in excess of 5%. This level of error is considered better than that provided by tuned Equation of State (EOS) models, which are currently in common use for the estimation of reservoir fluid properties. In addition to improved accuracy, the proposed ANN architecture avoids the ambiguity and numerical difficulties inherent to EOS models and provides for continuous improvements by the enrichment of the ANN training database with additional data. Also, Osman et al. (2001) used a three-layer NN to estimate the formation volume factor at bubble point pressure. The data for developing the neural network were 803 published data sets from Malaysia, middle East, Gulf of Mexico and Colombia. The input layer had four neurons to cover gas oil ratio, API gravity, relative gas density and reservoir temperature as input data and the hidden layer included five neurons. The developed model represents good accuracy compared with the correlations with absolute average error of 1.789% and correlation coefficient of 0.988.

3. Artificial neural networks (ANNs)

McCulloch and Pitts introduced the first ideas about NN with model of an elementary computing neuron in 1943 and after a few

Table 1
Summary of studies on prediction of PVT properties by ANNs.

Researchers	Year	Output	Network Structure	Region	Error
Gharbi and Elsharkawy	1997a	–P_b –B_{ob}	4–8–4–1 4–6–6–1	Middle East crude oils	Decrease
Gharbi and Elsharkawy	1997b	–P_b –B_{ob}	Three-layer ANN	Universal	Less improvement than the Middle East ANN model
Elsharkawy	1998	–B_{ob} –Oil formation volume factor solution –Gas–oil ratio –Oil viscosity –Saturated oil density –Undersaturated oil Compressibility –Evolved gas gravity	Radial basis function (RBF)	–	Show much less than the empirical methods
Varotsis et al.	1999			Universal	0.5–2.5%
Osman, E.A.	2001	–B_{ob}	4–5–1	Universal	AAE = 1.789% R = 0.988
Eissa M.	2004	–P_b –B_{ob}	4–10–10–1 5–8–8–1	Oil systems in California	AAE (B_{ob}, P_b) = 0.030704, 0.00368