Journal of Petroleum Science and Engineering 73 (2010) 248–257

Contents lists available at ScienceDirect

Journal of Petroleum Science and Engineering

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

Using artificial neural networks to estimate the *z*-factor for natural hydrocarbon gases

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ARTICLE INFO

Article history:
Received 18 November 2009
Accepted 6 July 2010

Keywords:
z-factor
gas compressibility factor
artificial Neural Network
DAK
numerical reservoir simulator
gas flow simulator

ABSTRACT

Gas compressibility factor (*z*-factor) is an important parameter widely used in petroleum and chemical engineering. Accurate and fast calculation of this parameter is of crucial need and challenges a large number of simulators used in petroleum engineering.

The Standing–Katz chart was published in 1942 and since then has been considered an industry standard. Several methods have been tried and developed to calculate *z*-factor by fitting models on the smoothed Standing–Katz data. Some of these models are the Dranchuk and Abou-Kassem (DAK), the Nishiumi–Saito, the Nishiumi, and the Brill–Beggs correlations. All models developed afterwards the Standing–Katz charts present some limitation like instability close to certain boundaries, convergence, and/or accuracy. In fact, different correlations tend to fit better to a particular area of the domain for P_{pr} and T_{pr} (pseudo-reduced pressure and temperature), but fail badly close and beyond to their limits. Also, most correlations require iterative procedures to obtain the corresponding *z*-factor, and may even present different results dependent on the initial guess for the initial iteration. The DAK correlation is one of the most widely used models.

In this study we propose and develop a methodology to obtain *z*-factors for Natural Hydrocarbon Gases using Artificial Neural Networks (ANN). Data obtained directly from the Standing–Katz and Katz compressibility charts were used to train several topologies of ANN. The input parameters in the ANN are the pseudo-reduced pressure and temperature and the output is the *z*-factor. Two of the successful networks have two hidden layers. The first ANN uses five neurons in each hidden layer and the second ANN uses ten neurons in each hidden layer (called 2-5-5-1 and 2-10-10-1 networks respectively). These topologies were trained with the data from the charts using a back-propagation training algorithm. The results are compared with the charts (with values not used during the training section), along with the results obtained using DAK correlation. In addition, performance comparisons were made between the ANN model and the DAK correlation. In both situations, the ANN models are superior to the DAK correlation. In addition, the ANN model covers a wider range of P_{pr} and T_{pr}, which surpasses the limits of all other correlations together. Typically, the time needed to obtain results for a 2-5-5-1 network corresponds to the time of one single iteration needed for the DAK correlation. The paper discusses these results, and provides the weight sets (values of synapses and biases) needed to reproduce the ANN, which can be easily implemented in an electronic spreadsheet.

1. Introduction

Equations of state (EOS), i.e., relationships between pressure, temperature, volume, and composition of matter, have been used widely in almost every branch of engineering, in particular for those industries dealing with gases.

The gas compressibility factor (*z*-factor), a parameter that measures the deviation for a real gas from the ideal gas, is a key parameter in almost all calculations for gases. The principle of corresponding states indicates that all gases, when compared at the same reduced pressure (P_r) and reduced temperature (T_r),[1] have approximately the same compressibility factor (Cengel and Boles, 2007) (Danesh, 1998). This principle facilitates the development of general EOS and the elaboration of general experimental charts expressed in terms of the reduced properties. Therefore, the compressibility of a pure gas at a given

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[1] A reduced property is the property divided by the value of the property at the thermodynamical critical point.

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doi:10.1016/j.petrol.2010.07.006

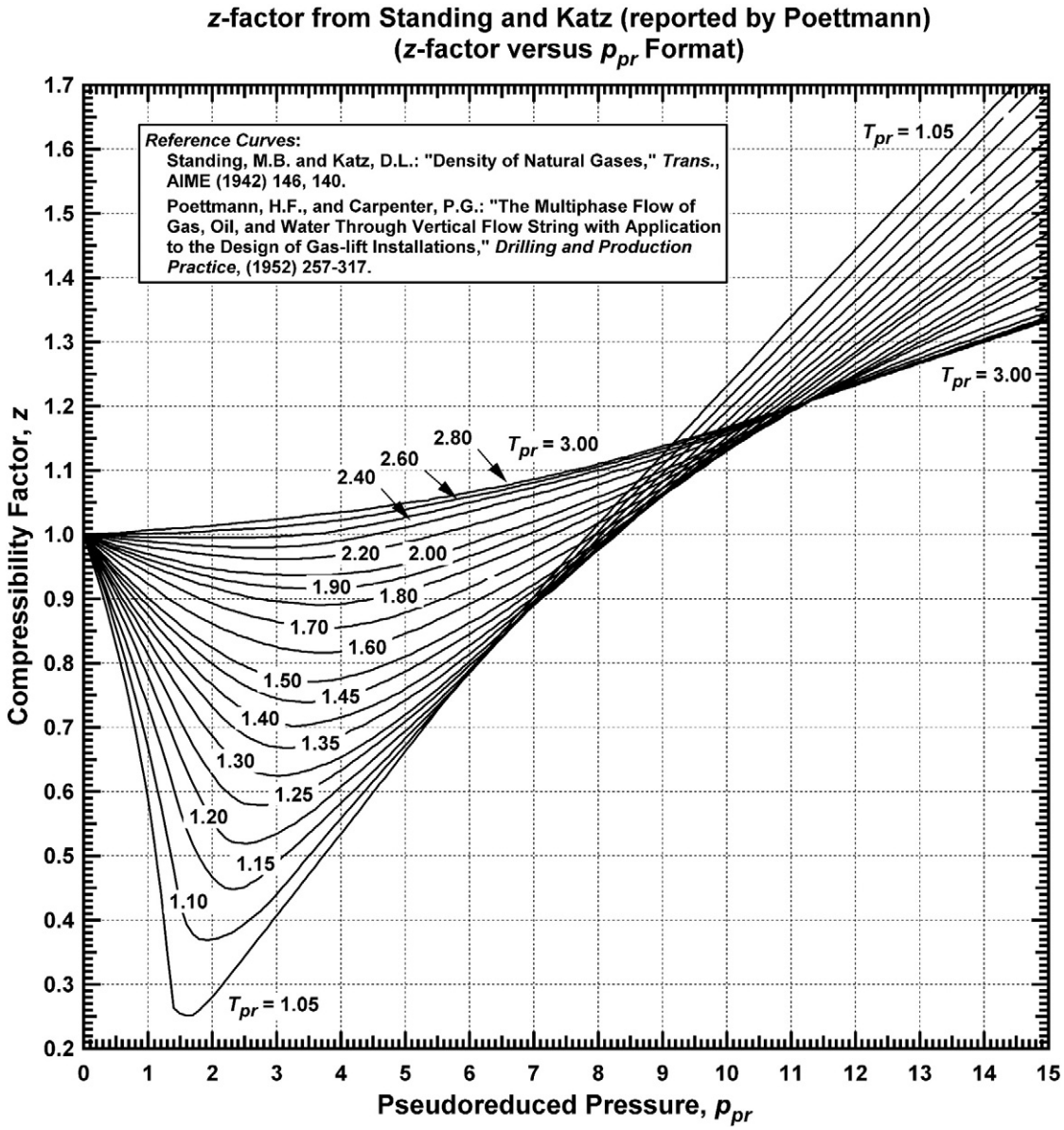

Fig. 1. *z*-factor from Standing and Katz (Standing and Katz, 1942).

pressure and temperature can be obtained from the reduced pressure and temperature by using either the EOS or the experimental chart. Particularly for natural hydrocarbon gases, the charts due to Standing and Katz (Fig. 1 (Standing and Katz, 1942)) and Katz (Fig. 2 (Katz et al., 1959)) are standards in Oil and Gas (O&G) industry.

The Standing and Katz chart and the Katz chart were developed from experimental data for natural hydrocarbon gases. Since these gases are not pure gases but a mixture of a large number of hydrocarbon gases, the pseudo-reduced pressure (P_{pr}) and the pseudo-reduced temperature (T_{pr}) were used.[2]

Different investigators have successfully reproduced those charts, at least under some limited conditions, by means of numerical correlations based on various equations of state, and these have been widely used for numerical simulation in various applications. One of these correlations is due to Dranchuk and Abou-Kassem (DAK) as described in Section 2.

The purpose of this study is to produce an efficient and accurate procedure to calculate the *z*-factor for natural hydrocarbon gases (from the pseudo-reduced pressure and temperature) by reproducing Standing and Katz charts and Katz charts using an Artificial Neural Network (ANN).

Despite the complex nature of natural hydrocarbon gases, which makes it difficult, if even possible, to establish a general EOS, an ANN can be very successful to calculate the *z*-factor from the pseudo-reduced parameters, as demonstrated in this study. The benefits of the ANN is highlighted by comparing the results obtained with it, and the results obtained using the DAK correlation, both in accuracy and in the computational effort (or cost). Previous successful uses of ANN are introduced briefly, and then the ANN used in this study is described.

It is important to emphasize that the ANN obtained in this study does not represent a model for gases. This study does not propose a scientific or physical model for gases, or a new equation of state, but it simply succeeds in obtaining a working, efficient, stable, and accurate way of calculating the *z*-factor from the pseudo-reduced parameters. This can be very useful, particularly if incorporated into numerical simulators.

[2] A pseudo-reduced property is the property divided by the value of the property at the thermodynamical pseudo-critical point. The latter is obtained by the molar fractional average of the critical property of the components of the natural gas in question.