



Are the reservoir fluid compositional grading data reliable?



Amir H. Mohammadi^{a,b,*}, Ali Eslamimanesh^c,
Farhad Gharagheizi^{b,d}, Poorandokht Ilani-Kashkouli^{b,d}

^a Institut de Recherche en Génie Chimique et Pétrolier (IRGCP), Paris Cedex, France

^b Thermodynamics Research Unit, School of Engineering, University of KwaZulu-Natal, Howard College Campus, King George V Avenue, Durban 4041, South Africa

^c Department of Chemical & Biomolecular Engineering, Clarkson University, Potsdam, NY 13699-5705, USA

^d Department of Chemical Engineering, Buinzahra Branch, Islamic Azad University, Buinzahra, Iran

ARTICLE INFO

Article history:

Received 11 July 2013

Received in revised form 20 October 2013

Accepted 30 October 2013

Available online 7 November 2013

Keywords:

Evaluation of data

Compositional grading data

Reservoir fluid

Thermodynamic model

Outlier

ABSTRACT

Outlier detection in compositional grading data of a reservoir fluid is the main objective of the present study. The experimental data of a petroleum reservoir fluid including the mole fractions of the fluid components at different depths (from around 1000 to about 1400 m) and at constant temperature of 361.15 K are investigated. The utilized algorithm applies the basis of a mathematical approach, in which the statistical Hat matrix, Williams plot, and the residuals of a compositional grading model results bring about the probable outliers detection. The range of applicability of the applied model and quality of the existing experimental data are also investigated. The reported results of a previously developed model using the Soave–Redlich–Kwong equation of state (SRK EoS) with Peneloux volume correction are employed to evaluate the compositional analysis of the species in different depths of the fluid column. It is interpreted from the obtained results that the applied model for estimation of the compositional gradients has wide ranges of applicability. In addition, we may conclude that there is no outlier or probable doubtful datum in the investigated experimental datasets.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

Variations in pressure, temperature, composition and PVT properties of reservoir fluids with depth are normally found in petroleum reservoirs [1–20]. For instance, the temperature has been reported to vary 0.02–0.03 K/m and bubble point pressure can change up to 0.11 MPa/m [2,3]. As the depth of a reservoir increases, the concentration of lighter components decreases while the concentration of heavier components increases [1]. Such compositional gradients are of much importance when the petroleum fluid column is deep. It has been observed that the concentration of methane in an heavy oil reservoir can be decreased up to 20% over a 81 m depth increase [3]. The compositional grading of a reservoir fluid column is of significance for primary depletion of the reservoir, sampling from the fluid column within the reservoir, and determination of the depth of its oil–gas contact [1–4].

Gravity and temperature gradients generally play the main role in compositional variations of the petroleum reservoir fluids. Since

experimental measurements of the compositions of a real reservoir fluid at different depths are generally difficult, there is a need to develop reliable thermodynamic models to predict the subsequent compositional variations.

The compositional grading models can be grouped normally into isothermal [1,2,21] and non-isothermal [1,22] models. The starting point of the model development is to evaluate the difference between the chemical potential of a component in different depths (locations in the reservoir). Although temperature gradient brings about heat flow between different points of reservoir, the thermodynamic equilibrium assumption of gravity segregation is generally considered as a basis for the compositional grading thermodynamic modeling. The effects of temperature on the compositional gradients may be negligible compared with gravity effects. Furthermore, calculations of heat flux, heat diffusions and their effects on residual enthalpies and finally on chemical potentials of components throughout the reservoir enhance the complexity of the non-isothermal model. Therefore, the isothermal compositional grading model seems to be preferable for practical purposes.

As mentioned earlier, the corresponding experimental compositional grading data are scarce in open literature. Furthermore, there has been no method proposed in open literature so far to check the reliability of such data. Hence, it is of interest

* Corresponding author at: Institut de Recherche en Génie Chimique et Pétrolier (IRGCP), Paris Cedex, France.

E-mail address: a.h.m@irgcp.fr (A.H. Mohammadi).

to check the quality of these data as well as the applicability domain of the isothermal compositional grading model for its prediction. In this work, a statistical method is applied for this purpose.

2. Isothermal thermodynamic model

The previously reported results of an available model in the literature [1] are used in this communication. The elements of the model are as follows: at isothermal equilibrium conditions, the total chemical potential of a component is the same at all positions in a closed system. Therefore, the difference between the intrinsic chemical potential of components reduces to the effect of the depth in the fluid column evaluated by the following equation [1]:

$$\mu_i(h) - \mu_i(h^0) = M_i g(h - h^0) \quad (1)$$

where μ is the chemical potential, subscript i refers to component i in the fluid mixture, M is the molecular weight, and h denotes the depth. The superscript 'o' stands for a reference depth. The chemical potential can be written in terms of fugacity or fugacity coefficient, pressure and composition as follows [1]:

$$d\mu_i = RT d \ln(f_i) = RT d \ln(\varphi_i z_i P) \quad (2)$$

In Eq. (2), R is the universal gas constant, T is temperature, φ is fugacity coefficient, z is the overall mole fraction of the species, and P stands for pressure. Eq. (2) is only available at isothermal conditions. Introducing Eq. (2) into Eq. (1) yields [1]:

$$\ln f_i^h - \ln f_i^{h^0} = \frac{M_i g(h - h^0)}{RT} \quad (3)$$

The fugacity of component i can be evaluated using the overall composition of the species as follows:

$$f_i = P_i z_i \varphi_i \quad (4)$$

where z is the overall composition of component i . Eq. (3) can be re-written as follows:

$$\ln(\varphi_i^h z_i^h P^h) - \ln(\varphi_i^{h^0} z_i^{h^0} P^{h^0}) = \frac{M_i g(h - h^0)}{RT} \quad i = 1, 2, \dots, N \quad (5)$$

Where N is the number of components. An additional equation can be written regarding the unity of summations of the mole fractions:

$$\sum_{i=1}^N z_i = 1 \quad (6)$$

Thus, there are $N+1$ variables for a given depth in the fluid column. Solving $N+1$ equations with $N+1$ variables leads to obtaining the molar compositions and pressure with depth. An appropriate equation of state can be applied for determination of the required variables. In this work, the results of an isothermal thermodynamic model [1] employing the Soave–Redlich–Kwong equation of state (SRK EoS) [23] with Peneloux volume correction [24] have been used for statistical evaluation of the experimental data. Furthermore, the applied model [1] utilizes the procedure proposed by Pedersen et al. [25] for fluid characterization.

3. Experimental data

The experimental data of a petroleum reservoir fluid reported by Creek and Schrader [26] in 1985 have been herein evaluated. The data includes the mole fractions of the fluid components at different depths (from around 1000 to about 1400 m) and at constant temperature of 361.15 K.

4. Theory

4.1. Leverage method

Detection of the outliers is to diagnose individual datum (or a dataset) that may differ from the bulk of the data (a database) [27–30]. The proposed methods for this purpose normally consist of simultaneous numerical and graphical algorithms [27–30]. The Leverage method [27–30] (employed here) utilizes the values of the residuals (i.e. the deviations of a model results from the corresponding experimental data) and a matrix (Hat matrix) composed of the experimental data and the represented/predicted values obtained from the model [27–30]. Hence, a suitable mathematical model is also required to pursue the calculation steps of the algorithm [27–30].

The Leverage or Hat indices are determined as a Hat matrix (H) with the following definition [27–30]:

$$H = X(X^t X)^{-1} X^t \quad (7)$$

where X is a two-dimensional matrix composed of n data (rows) and p model parameters (columns) and t stands for the transpose matrix. The Hat values of the chemicals in the feasible region of the problem are, as a matter of fact, the diagonal elements of the H matrix.

The Williams plot is later sketched for graphical identification of the suspended data or outliers on the basis of the calculated H values through Eq. (7). This plot shows the correlation of Hat indices and standardized cross-validated residuals (R'), which are defined as the difference between the represented/predicted values and the implemented data as follows [27]:

$$R' = z_i^{\text{rep./pred.}} - z_i^{\text{exp.}} \quad (8)$$

where rep./pred. and exp. represent the represented/predicted and experimental overall mole fractions, respectively. A warning Leverage (H^*) is generally fixed at the value equal to $3p/n$, where n is number of training points and p is the number of model input parameters plus one [27–30]. The leverage of 3 is normally considered as a “cut-off” value to accept the points within ± 3 range (two horizontal red lines) standard deviations from the mean (to cover 99% normally distributed data) [27–30]. Existence of the majority of data points in the ranges $0 \leq H \leq H^*$ and $-3 \leq R' \leq 3$ reveals that the representations/predictions of the model are done in its applicability domain. “Good High Leverage” points are located in domain of $H^* \leq H$ and $-3 \leq R' \leq 3$. The Good High Leverage can be designated as the ones, which are outside of applicability domain of the applied model [27–30]. In other words, the model is not able to represent/predict the following data at all. The points located in the range of $R' < -3$ or $3 < R'$ (whether they are larger or smaller than the H^* value) are designated as outliers of the model or “Bad High Leverage” points. These erroneous representations/predictions can be attributed to the doubtful data [27–30].

5. Results and discussion

The absolute relative deviations (ARDs) of the thermodynamic model [1] results are presented in Table 1 along with the experimental data [26]. As can be seen, the deviations of the predictions from the corresponding experimental data [26] are generally acceptable to be used for the Leverage statistical approach [27–30].

To pursue our objectives, the H values have been calculated through Eq. (7) and the Williams plots have been sketched in Fig. 1. The whole calculated H and R values are presented in Table 2. The

Download English Version:

<https://daneshyari.com/en/article/202232>

Download Persian Version:

<https://daneshyari.com/article/202232>

[Daneshyari.com](https://daneshyari.com)