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Original article

Presenting decision tree for best mixing rules and Z-factor correlations and introducing novel correlation for binary mixtures

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The significance of gas compressibility factor in petroleum engineering encourages the researchers to employ the most accurate and precise methods for estimation of this factor. Commonly, empirical correlations due to their simplicity have been referred more than other approaches for prediction of Z-factor. There is no clear and reliable report to address an appropriate combination of correlation and mixing rule for each type of gas. In the present study, combination of several empirical correlations and mixing rules is examined and a decision tree is constructed to suggest best combination for each gas system. For this reason, 2329 experimental data were used for analysis. According to the results, Leland–Mueller mixing rule/Sanjari and Lay correlation is the best combination for sour and natural gas. Also, Van Ness–Abbot mixing rule/Hall–Yarborough correlation, Stewart–Burkhardt–Voo mixing rule/Heidarian correlation and Satter–Campbell mixing rule/Papay correlation are the most appropriate combination for gas condensate, binary and ternary mixtures respectively.

For binary mixtures, a robust and novel empirical correlation was developed based on Kay mixing rule to estimate Z-factor. The results employed how good the new correlation is in agreement with the experimental data with significant R-squared 0.9843.

1. Introduction

Obtaining thermo-physical properties of oil and gas reservoirs is crucial for engineering purposes. The significance of this issue becomes more apparent considering the role of these properties in determination of reservoir hydrocarbon pore volume, gas solubility and other reservoir chief features. Compressibility factor (Z-factor) is an important one property for compressible fluids, as many thermo-physical properties like heat capacity, enthalpy, entropy and gas formation volume factor are functions of Z-factor. Also, its application in practical purposes such as gas transmission systems, hydrate formation and diffusivity equation of gas reservoir is well documented [1–3]. Thus, accurate prediction of Z-factor is an important step in engineering applications.

Different ways of obtaining Z-factor include PVT laboratory measurement, empirical correlations and equations of state (EOS) [4]. Also, considering costly PVT experiments and complicated procedure of EOS persuade the researchers to apply empirical correlations as an estimator. Several researchers attempted to develop empirical correlations. For example, Beggs and Brill developed their correlation based on Standing and Katz chart [5], but it is not applicable for reduced temperature less than 0.92 [5,6]. The proposed correlations conventionally developed as function of reduced pressure and temperature.

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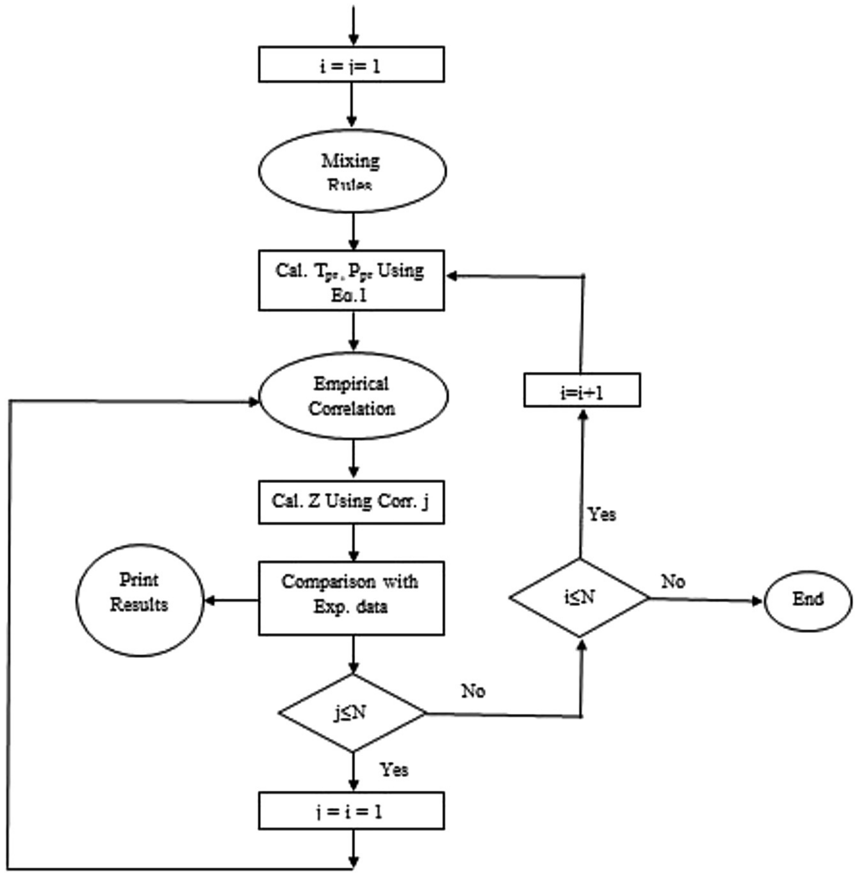

Fig. 1. Calculation flowchart.

There are some correlations explicit in reduced density, e.g. Dranchuk–Abu-Kassem correlation [7], which tacitly is a function of reduced pressure and temperature. Also, many correlations are functions of pseudo pressure and temperature, e.g. such as Hall–Yarborough [8] and Heidarian et al. correlation, which was developed based on 1220 experimental data [9]. However, the declared limitation in using pseudo pressure and temperature may cause some difficulties [9]. In addition, some correlations are developed based on other famous equations such as Virial EOS, e.g. Sanjari and Lay [10]. Similar to Heidarian et al. correlation, Sanjari and Lay correlation also has some limitations in range of application. Traditional empirical correlations are generally developed using classical regression method. For instance, Shell Oil Company and Papay correlations were developed based on regression and fitting method [1,11]. Beside mentioned correlations, there are some which were developed using smart techniques such as Aziz and Rayes [12,13]. The general form of these correlations is more complicated than old generation correlations.

Also, for obtaining reduced pressure and temperature of gas mixtures, several mixing rules have been proposed on date. The simplest mixing rule was proposed by Kay [14]. Sutton introduced a mixing rule for gas reservoirs containing plus fraction heavy end (C_{7+}) [15]. This mixing rule was proposed by applying Standing and Katz chart [15]. On the other hand, there are some complicated mixing rules such as that of Leland–Mueller [14], which is a function of reservoir composition, temperature and pressure. Typically, traditional mixing rules are functions of reduced pressure and temperature. Similar to other types of empirical correlations, the empirical mixing rules have been commonly developed by regression and fitting the experimental implemented data. Other traditional mixing rules applied in the current paper are Joffe method [16], Prausnits–Gunn [17], Stewart–Bukhardt–Voo [14], Satter–Campbell [14], Van Ness–Abbot [18], Teja–Thurner–Pasumarti [19] and Redlich–Kwong–Abbott [1]. All mentioned correlations are implicit functions of pseudo critical pressure and temperature.

Details of these mixing rules are given in Appendix A. Also, details of empirical correlations used in this work can be found in Mohamadi-Baghmolaei et al. [20].

In this study, different combinations of empirical correlations and mixing rules are tested to determine the best couple for each category of gas mixture. To do this, Kay Rule, Joffe, Prausnits–Gunn (PG), Leland–Mueller (LM), Stewart–Bukhardt–Voo (SBV), Satter–Campbell (SC), Van Ness–Abbot (VNA), Teja–-Thurner–Pasumarti (TTP), Redlich–Kwong–Abbott (RKA) mixing rules are employed, in combination with the nine mentioned empirical correlations including Dranchuk and Abu-Kassem (DA) [7], Hall–Yarborough (HY) [8], Heidarian et al. (HD) [9], Sanjari and Lay (SL) [10], Shell Oil Company (SOC) [1], Beggs and Brill (BB) [5], Azizi (AZ) [12], Papay (PP) [11] and Rayes at el. (RY) [13]. A data base comprising 2329 experimental data sets of different types of gases is used for this study. Next, a novel robust empirical correlation is introduced for binary mixtures using 1742 experimental data. The new correlation is able to cover vast ranges of input pressure and temperature with high accuracy.

2. Methodology

Several researchers developed empirical correlations which were explicit in reduced pressure and temperature of gas mixture. Generally, theses correlations require pseudo critical