Comparison of Distribution Functions for Characterization of C_{7+} Fraction in One of Iranian Oil Field

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Abstract

In characterization of wide boiling range heptane plus (C7+) fractions in addition to bulk properties such as molecular weight (MW), specific gravity (SG), etc., properties distribution is also required. Bulk properties can be measured easily but determination of properties distribution is more costly and time consuming. So the characterization methods is used for determining the properties distribution. Methods selected for the characterization of reservoir fluids have significant impact on the estimation of physical properties and phase behavior needed in reservoir simulation for petroleum production. Characterization of reservoir fluids involves representing the fluid as a continuous, semi-continuous mixture or through a number of components/pseudocomponents with known basic characterization data. Understanding of various characterization schemes and their limitations is the key to selecting the right one in a reservoir simulator. The main objective of these paper is to compare the results of characterization methods for one of Iranian south oil field to determine the best method that is compactible with that reservoir fluid. The results show that all models can estimate the mole fraction distribution very close to the experimental data from C_7 to C_{30+} but the average absolute error for single carbon number (SCN) model is lower than other models for this reservoir fluid.

Key words: PDF, distribution model, characterization, plus fraction, PVT

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1. Introduction

Petroleum fractions are complex mixtures of mainly paraffinic, naphthenic and aromatic compounds. For these types of mixtures, it is unpractical to list all of the components, which have carbon numbers equal to or greater than 6 or 7, and are presented as C_{6+} or C_{7+} fractions. Characterization of C_{7+} fractions is an important step in the application of equations of state for pressure–volume–temperature (PVT) predictions and phase behavior calculations of gas condensates and petroleum fractions [1].

Characterization of reservoir fluids and crude oils mainly involves characterization of hydrocarbon plus fractions generally expressed in terms of C_{7+} fractions. A C_{7+} fraction of a crude oil has a very wide boiling range in comparison with a petroleum product and contains more complex and heavy compounds. Usually the only information available for a C_{7+} fraction is the mole fraction, molecular weight, and specific gravity. The characterization procedure involves how to present this mixture in terms of arbitrary number of sub-fractions (pseudo-components) with known mole fraction and molecular weight. This approach is called pseudoization. The main objective of this paper is to present methods of characterization of hydrocarbon-plus fractions and compare their results for one of Iranian oil field, which involves prediction of distribution of hydrocarbons in the mixture [1, 2].

1.1. Exponential Model [2, 3, 4]

The exponential model is the simplest form of expressing distribution of SCN groups in a reservoir fluid. Several forms of exponential models proposed by Lohrenz (1964), Katz (1983), and Pedersen (1984) have been reviewed and evaluated by Ahmed. The Katz model gives an easy method of breaking a C7+ fraction into various SCN groups as:

$$x_n = 1.38205 \exp(-0.25903 CN) \tag{1}$$

where x_n is the normalized mole fraction of SCN in a C_{7+} fraction and CN is the corresponding carbon number of the SCN group. Yarborough and Pedersen et al have suggested to assume a logarithmic distribution of the mole fraction x_n versus the carbon number CN or Mw as:

$$\ln x_n = A + BM_{Cn} \tag{2}$$

When partial analysis of the C_{7+} is available, the constants can be determined by regression, minimizing the sum of squared differences between the calculated and measured concentration of known SCN groups.

1.2. Gamma Distribution Model [2, 3, 4]

The gamma distribution model has been used to express molar distribution of wider range of reservoir fluids including black oils. Characteristics, specifications, and application of this distribution model to molecular weight and boiling point have been discussed by Whitson in details. The probability density function in terms of molecular weight "M" for this distribution model as suggested by Whitson has the following form:

$$F(M) = \frac{(M-\eta)^{\alpha-1} \exp\left(-\frac{M-\eta}{\beta}\right)}{\beta^{\alpha}\Gamma(\alpha)} \tag{3}$$

where α, β and η are three parameters that should be determined for each mixture and $\Gamma(\alpha)$ is the gamma function to be defined later. Parameter η represents the lowest value of M in the mixture. To estimate parameter β the following equation can be used:

$$\beta = \frac{M_{7+} - \eta}{\alpha} \tag{4}$$

Whitson et al. suggest an approximate relation between η and α as follows:

$$\eta = 110\left(1 - \frac{1}{1 + 4.043\alpha^{-0.723}}\right) \tag{5}$$

The value of α ranging approximately between 0.5 to 2.5 for typical reservoir fluids, controls the distribution skewness. Values of α equal to, or less than one represent mixtures with continuous decline in concentration, whereas values more than one demonstrate a maximum in concentration.

Finally, the mole fraction of SCN group, x_n, can be determined simply by integrating the distribution function between $(n-1)$ and n:

$$x_n = \int_{M_{n-1}}^{M_n} F(M)dM \tag{6}$$

1.3. Generalized Distribution Model [3, 4]

An extensive analysis was made on basic characterization parameters for C_{7+} fractions of wide range of gas condensate systems and crude oils, light and heavy as well as narrow and wide petroleum fractions. Based on such analysis the following versatile equation was found to be the most suitable fit for various properties of more than 100 mixtures:

$$F(P^*) = \frac{B^2}{A} P^{*B-1} \exp\left(-\frac{B}{A} P^{*B}\right) \tag{7}$$

where,

$$P^* = \frac{P - P_0}{P_0} \tag{8}$$

where P is a property such as molecular weight (M) or specific gravity (SG), P_o is a parameter specific for each property (M_o and SG_o) and each sample. Usually cumulative mole fraction, x_{cm} is used for molecular weight. A and B are two other parameters which are specific for each property and may vary from one sample to another. Equation has three parameters (Po, A, B); however, for more than 100 mixtures investigated it was observed that parameter B for each property is the same for most samples reducing the equation into a two-parameter correlation. Parameter P_o corresponds to the value of P at $x_c = 0$, where $P^* = 0$.

Finally, the mole fraction of SCN group, x_n, can be determined simply by integrating the distribution function between $(n-1)$ and n:

$$x_n = \int_{P^*_{n-1}}^{P^*_n} F(P^*) dP^* \tag{9}$$

2. Case Study

In this section, the above models are evaluated for one of Iranian south oil fields and the results are presented. The components (C_7 to C_{16+}) and their normalized composition of crude oil sample are given in table 1.

Table 1: **One of Iranian crude oil composition and properties**

Components	Mol%
C_7	9.39
C_8	9.95
C_9	8.86
C_{10}	8.41
C_{11}	7.03
C_{12}	5.89
C_{13}	5.36
C_{14}	4.35
C_{15}	4.22
C_{16+}	36.53

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Mw C_{16+}	406
S.G C_{16+}	0.933

By using the above data, the constants of each distribution models, which were explained, were determined and the crude sample plus fraction characterized to C_{30+}. The results of each model are given in table 2.

Table 2: Characterization results from distribution models from C_7 to C_{30+}

Components	Mol% Experiment	Katz Mol% Cal.	Whitson Mol% Cal.	Riazi Mol% Cal.
C_7	9.39	9.392	9.95	-
C_8	9.95	9.95	8.20	10.19
C_9	8.86	8.862	7.44	8.77
C_{10}	8.41	8.411	6.23	7.04
C_{11}	7.03	7.031	5.72	6.24
C_{12}	5.89	5.89	5.28	5.57
C_{13}	5.36	5.36	4.89	5.00
C_{14}	4.35	4.351	4.67	4.64
C_{15}	4.22	4.219	4.30	4.16
C_{16}	3.69	3.585	3.73	3.53
C_{17}	3.13	3.152	3.15	2.91
C_{18}	2.79	2.795	2.57	2.34
C_{19}	2.65	2.522	2.19	1.96
C_{20}	2.36	2.275	2.35	2.07
C_{21}	1.99	1.983	1.92	1.67
C_{22}	1.86	1.836	1.50	1.29
C_{23}	1.57	1.656	1.60	1.36
C_{24}	1.38	1.494	1.54	1.30
C_{25}	1.19	1.336	1.43	1.19
C_{26}	1.09	1.206	1.22	1.01
C_{27}	1.11	1.097	1.13	0.93
C_{28}	0.93	0.99	1.01	0.82
C_{29}	1.33	0.908	0.95	0.77
C_{30+}	9.47	9.701	14.18	11.07
Mw C_{30+}	750	739.7	561.8	566
S.G C_{30+}	1.011	1.00956	-	-

3. Result and Conclusion

As it is shown in table 2, by considering the results of each model for the crude oil sample, it is found that the exponential model gives better result for the characterization of heptane plus fraction of this fluid. The average absolute error of the exponential model compared to experimental data is 1.11%. Also, for the gamma and generalized distribution models this error is 2.94% and 3.4% respectively which means that the gamma model gives better result for this sample.

The results of table 2 are illustrated in figure 1. As it is shown, the gamma and generalized distribution models performance for characterization of plus fraction for this Iranian oil field improve as it approach the heavier fraction.
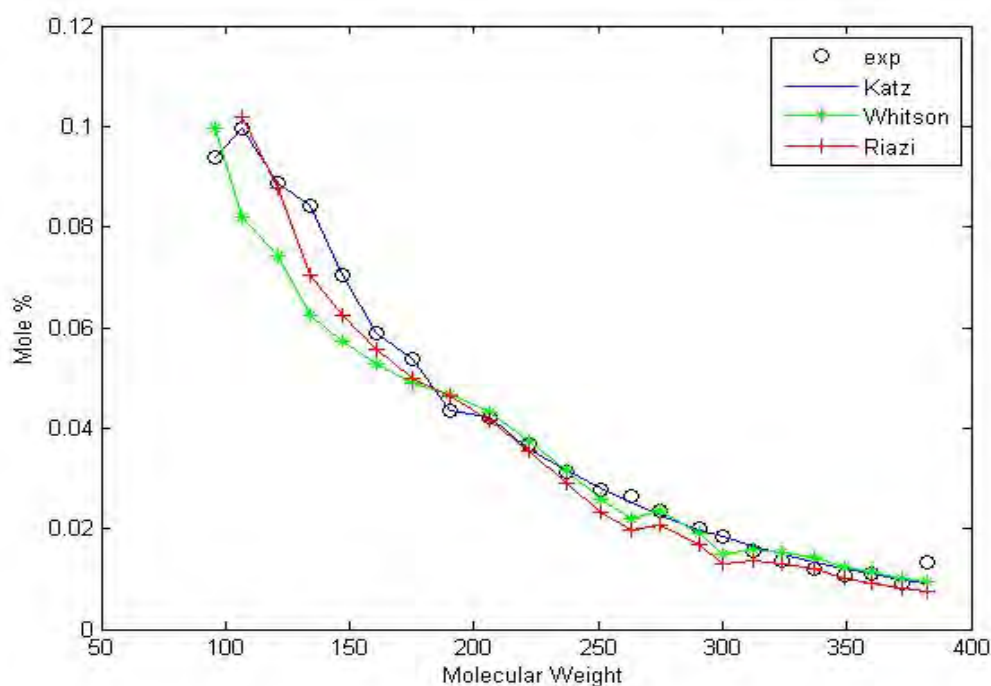

Figure 1: Mole % vs Mw plot of distribution models

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