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# A new heuristic model for estimating the oil formation volume factor

Mohammad Reza Mahdiani*, Mohammad Norouzi

*Faculty of Petroleum Engineering, Amirkabir University of Technology (Tehran Polytechnic), Hafez Avenue, Tehran, Iran*

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The necessity of oil formation volume factor ($B_o$) determination does not need to be greatly emphasized. Different types of reservoir oil have specific conditions which impart the hydrocarbon's major properties, among which is the oil formation volume factor. Therefore, it seems imperative to construct a model capable of estimating the value of oil formation volume factor. Previous studies have resulted in a number of correlations for oil formation volume factor estimation; however, a large portion of them do not provide an acceptable accuracy (at least in some range of data) and cause a huge error at these points. Some others are not flexible enough to be tuned for a specific type of reservoir oil and a comprehensive piece of work does not exist as well in order to compare the applicability of the new models for estimating the oil formation volume factor. In this research, a model based on simulated annealing (SA) has been built in terms of temperature, solution gas-oil ratio, and gravity of oil and gas to predict the oil formation volume factor. This model is compared with the models proposed in the most recent studies, which shows the greater performance of the new method. In addition, in this paper the models of the recent years were compared with each other and their applicability were discussed. Aiming to compare the models, 420 data points were selected and the estimated values of each model for oil formation volume factor were compared with their experimental ones.



## 1. Introduction

Hydrocarbon liquids possess a set of properties. One of them is oil formation volume factor ($B_o$), defined as the ratio of oil volume at reservoir conditions to its volume at surface (standard) conditions. This property plays an important role in calculating some of the prominent petroleum engineering terms and parameters. For instance, reserve estimation [1], gas lift modelling [2], reservoir production calculation [3], stability of flow [4,5], flow. In addition, this property appears in optimization (e.g. optimizing the rate of production) and simulation problems.

The underground oil reservoirs are classified into three categories based on their value of average pressure: below bubble point pressure ($P < P_b$), at bubble point pressure ($P=P_b$) and above bubble point pressure ($P > P_b$). An amount of free gas exists in the porous hydrocarbon reservoir when pressure is below bubble point pressure [6]. As a result of the compressibility of fluids (oil and gas), changing the reservoir pressure affects the oil formation volume factor (considering its definition). At higher pressures, when the value of pressure outweighs the bubble point pressure, the oil formation volume factor can be calculated conveniently provided that the compressibility factors and oil formation volume factor at bubble pressure are known [7–9]. Therefore, it seems necessary to have a value for oil formation volume factor at bubble point pressure for further calculations.

When there is no possibility for measuring the oil formation volume factor values on an experimental or analytical basis, correlations present themselves as a means. Hence, a precise correlation proves to be critical to calculate the oil formation volume factor for different ranges of parameters. In the literature, several correlations have been propounded to estimate the oil formation volume factor while a particular range of parameters is assigned to them that indicates the range in which they operate acceptably exactly [10]. This limitation can be eliminated by applying a new introduced tool (simulated annealing programming [11,12]) to build an

* Corresponding author.
*E-mail address:* mahdiani@aut.ac.ir (M.R. Mahdiani).
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efficacious model capable of estimating the oil formation volume factor. Developing mathematical models is very common in different aspects of science and engineering [13,14]. Here, this method is used and the resulted model performs the task of estimation in a wide range of temperature, solution gas oil ratio, and gravity of oil and gas. This model is very accurate and for proving that it has been compared with the most recent models in literature.

### 1.1. Literature review

Several researchers have proposed a number of correlations to find and exact value of the oil formation volume factor of different oil in various situations. To prepare an estimating correlation in terms of gas gravity, oil gravity, gas-oil ratio, reservoir pressure and temperature, 117 data sets were manipulated by Katz [15]. Estimation of oil formation volume factor which only requires four input parameters became accessible in 1947. Standing [16,17,18] did this by utilizing 105 experimental data which were gathered from 22 oil fields in California. An appropriate correlation which is capable of determining the oil formation volume factor in reservoirs produced with the depletion drive mechanism was made by Cronquist [19]. Vasquez and Begg [20] made efforts to derive a gas gravity dependent correlation in 1980. They used a number of 6000 experimental data points. In another case, Glaso [21] developed an equation for a special reservoir fluid that is comprised of methane gas dissolved in black oil. He assumed the concept of gas-oil equilibrium. As a result of the method of linear regression, a correlation for Middle East oils was introduced by Al-Marhoun [22,23] in 1988. Simultaneously, Abdul-Majeed [24], who worked on 119 hydrocarbon solutions, estimated the values of oil formation volume factor by implementing non-linear regression analysis. Based on separator pressure and temperature, Labedi [25]derived a correlation for the oil formation volume factor. In a similar work, Farshad [26] developed an estimating equation including these two factors. Gharbi et al. [27] constructed a proxy model using artificial neural network (ANN). This model facilitated the calculation of oil formation volume factor for Middle East oils. Parallel to this research, a correlation based on multiple regression analysis was developed by Elshrkway et al. [28] in 1997. Also, a different method of regression called multiple variable helped El-Banbi et al. [29] derive a correlation for oil formation volume factor. Bearing in mind that density is related to the oil formation volume factor, Sutton [30] developed a density correlation that would yield oil formation volume factor regarding the relationship in 2008. In 2009, El-Sebakhy [31] modeled a support vector machine network which was able to estimate the oil formation volume factor. The factors including separator gas-oil ratio and pressure, stock tank gravity and reservoir temperature were entered the regression calculations by Elmabrouk et al. [32] and another correlation was developed. Nassar et al. [33] represented the separator configuration (number of stages) as a new factor in addition to its pressure and temperature, and introduced a correlation for oil formation volume factor in 2013. In recent years a number of new methods have been used for estimating the oil formation volume factor. In 2014, Karimnezhad et al. [34] used the genetic algorithm to predict the oil formation factor. In addition in this year Torabia et al. [35] predicted the oil formation volume factor using three models of statistical analysis, artificial neural networks and three-dimensional modelling. They claimed that the statistical analysis had the best performance. Sulaimon et al. [36] used a group Method of Data Handling (GMDH) technique to estimate the oil formation volume factor. In 2015, Shokrollahi et al. [37] used an approach called committee machine intelligent system for predicting the oil formation volume factor. In 2016, Mahdiani et al. [38,39] studied the new methods for estimating the oil formation volume factor; they optimized the internal parameters of the neural network and then using that they found a model for oil formation volume factor. They used four different genetic programming models as well. Their models were adaptable in which their degree of accuracy and their complexity were settable.

There appears to be a large number of correlations devoted to estimate oil formation volume factor in the literature. Nevertheless, the main point is to specifically indicate the most accurate one. A comparison between these correlations has been the subject of a considerable number of studies made by researchers [40]. In 1994, Ghetto et al. [41] used 195 data points to perform this task. The Vasquez and Begg [20] model was proposed as an enhanced estimating tool. Almehaideb [42] ranked Al-Marhoun, Glaso and Standing respectively as the models which have the greatest accuracy. The processed data gathered from 13 oil fields yielded this result. In another research made by Godefroy [43], the Glaso and Al-Marhoun correlations were denoted as the best ones. In 2016, Mahdiani [38] surveyed different models including new models such as optimized artificial neural network and adaptive genetic programming models and concluded that the performance of the new models is better than traditional ones.

In this study, a new approach namely simulated annealing optimization, has been adopted to construct a new model which enables us to estimate the oil formation volume factor provided that simulated annealing optimization is implemented on a tree structure. Subsequently, this sophisticated model has undergone a comparison process aiming to compare it with the previously mentioned models claiming to have the highest precision. The corresponding results elucidate the efficient performance of this novel model. The new model of this paper is accurate and flexible. Using simulated annealing programming for developing models makes the developer enable to create easily model for a data set, have an explicit equation and be able to modify the model whenever a more extended dataset be available.

### 1.2. Using simulated annealing (SA) for modelling

Generally, simulated annealing is classified as one of the optimization evolutionary algorithms. However, in this research, its range of application is shifted to make it appropriate for modelling purposes. Hence, in order to present the model, the tree structure is used (Fig. 1). The flexibility tree representation has made it applicable in diverse fields of knowledge [44,45]. For instance, computer programming, mathematical equations, circuit design, identification

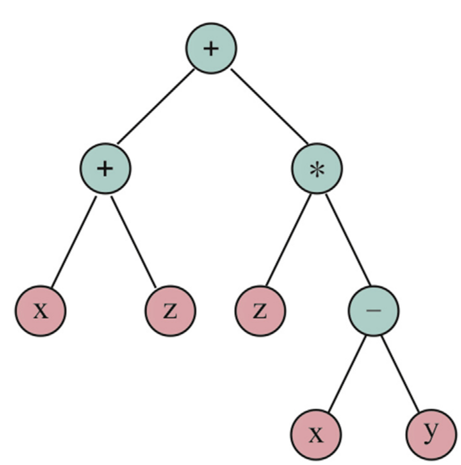


**Fig. 1.** Tree Structure, green shows the nodes and orange shows the terminals.

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