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Fuzzy Modeling and Experimental Investigation of Minimum Miscible Pressure in Gas Injection Process

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ABSTRACT

Knowledge about miscibility of injected gas in reservoir oils has a vital importance in gas injection process in petroleum reservoirs for enhanced oil recovery (EOR) goals. In other words, miscibility of the injected gas is highly depends on injection pressure and restriction of injection facilities. Thanks to these facts, minimum value of miscibility pressure should be specified accurately. To pass successfully the aforementioned issue, fuzzy logic method was utilized to specify minimum miscible pressure (MMP) of injected gas and reservoir oil. Moreover, different type of membership functions have been implemented such as curve shaped, triangular and trapezoidal shape. A large data banks which reported in open literature have been used in order to specify performance, deviations and precision of the developed fuzzy logic approaches. Furthermore, slim tube experiments have done on four different crude oil samples to determine their MMP values in contact with gas. Also, experimental results of this research have been matched accurately with corresponding outcomes of fuzzy logic approaches in comparison with conventional methods. According to the results gained from this research on the basis of statistical parameters, curve-shape membership function has higher superiority than other executed types of membership function. Outcomes of present work could be utilized for designing more precise, accurate and assured gas injection process by means of miscible displacement.

1. Introduction

Recovery from oil reservoirs can notably and conventionally gets improved through wide forms of the gas injection above minimum miscible pressure (MMP). In a certain amount of reservoir temperature, the lowest pressure at which the injected gas could accomplish the dynamic miscibility through multiple contacts with the oil is called the MMP. In fact, this is highly necessary to operate at or above this special sort of pressure in target oil reservoirs which are undergoing the gas injection operations to develop fully the miscibility for multiple contacts. Regardless of the considerable amount of time, energy and efforts which are required to implement the gas injection operation in a particular oil field, the inaccurate calculation of the MMP might results in some significant fatal consequences like as reaching to a lower rate of recovery which means concluding an ineffective process as a result of not meeting the desired level of the local displacement efficiency due to the two phase displacement, implying the immiscibility, because of the too low pressure of injection. The reverse, suggesting too much amount of MMP causes increasing exponentially the relevant cost of pressurizing the injected gas even though having a multi-contact miscible displacement resulting in meeting the goal of desired rate of oil recovery is a benefit of this type of overestimation [1–4].

Generally, the miscible injection process is a strong function of understanding thoroughly the behavior of the involved fractions. For instance, figuring the method of mixing the injected fluid and the reservoir fluid out at the given pressure and temperature condition is one of the important studying topics. Moreover, previous literatures have fully detailed the practical methods of measuring experimentally the MMP. In order to remove the problematic issues mostly relevant to timing and financing aspects of addressed laboratory procedures in the other research, great efforts have been put forth to substitute the numerical, logical and empirical correlation based methods [5–11].

As following of one this made attempts, in this contribution many efforts have been made to make practical the implementation of fuzzy logic based routs in the prediction of the minimum miscible pressure (MMP) of CO_2–oil system. In this contribution, fuzzy logic models with different membership functions have been

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applied to estimate the MMP according to the temperature (T), molecular weight (MW) of the C5+ and Vol./Int. The robustness, uncertainty and integrity of the developed fuzzy logic approach in estimating experimental CO_2–oil MMP from the open reported literatures [6,7,12–22] have been investigated. The generated results dictate this fact that the proposed fuzzy approach has a good exactness in estimating minimum miscible pressure (MMP) of CO_2–oil system while curve-shape membership function employed.

2. Slim tube experiment

Graphical illustration of the slim tube equipment which used in the current study is depicted in Fig. 1. The slim tube experiment is applied through a 40 ft long coiled stainless steel tubing. The mono-phase liquid core flood and weighting approach have been implemented to determine the permeability and porosity, correspondingly. Three steps including column cleaning, evacuating and weighing should be performed before each run. After that, Toluene is injected into the column and then 1.2 PV of reservoir oil is injected in order to displace the Toluene and saturate the porous media. To control system pressure a back pressure regulator has been utilized at the outlet of the slim tube. The rate of gas injection was 0.3 cc/hr and the density of the produced fluid is determined simultaneously by coupling a density meter to specify the breakthrough point. Furthermore, observing of the bubbles of gas in the transparent outlet is another way for determining the breakthrough point. There is also a gas-liquid separator and a gas meter to determine and acquire the produced oil and gas. In order to minimize heat losses of the used system, all parts of the system are insulated. To specify the breakthrough point, sampling is performed each 3 min time interval. Two different methods can be used to determine the breakthrough point. First is with the aim of the produced fluid appearance and second is plotting gas oil ratio (GOR) against time. The explained process is done for different system pressure and various compositions of injected gas. Finally, by plotting recovery factor of the injected gas versus corresponding system pressure, required curve is generated. MMP is a turning point of the aforementioned curve.

3. Fuzzy logic model

Fuzzy logic (FL), this cutting edge field of science, was initially proposed by Zade to deal with the problematic issues tuned with tastes of vagueness, ambiguity and uncertainty which we are supposed to encounter with them. This opportunity has become possible through the extension that has become created in the nature of the binary logic. In more details, each related attributes is known with a membership function which has divided into a certain number of subsets labeled with linguistic terms. This membership function covers a limited support in which every number located within determined with some membership degrees between 0 and 1 related to each subset. After that, there are some so called “IF-THEN” rules extracted either automatically or manually which are supposed to get fired for a number of input parameters

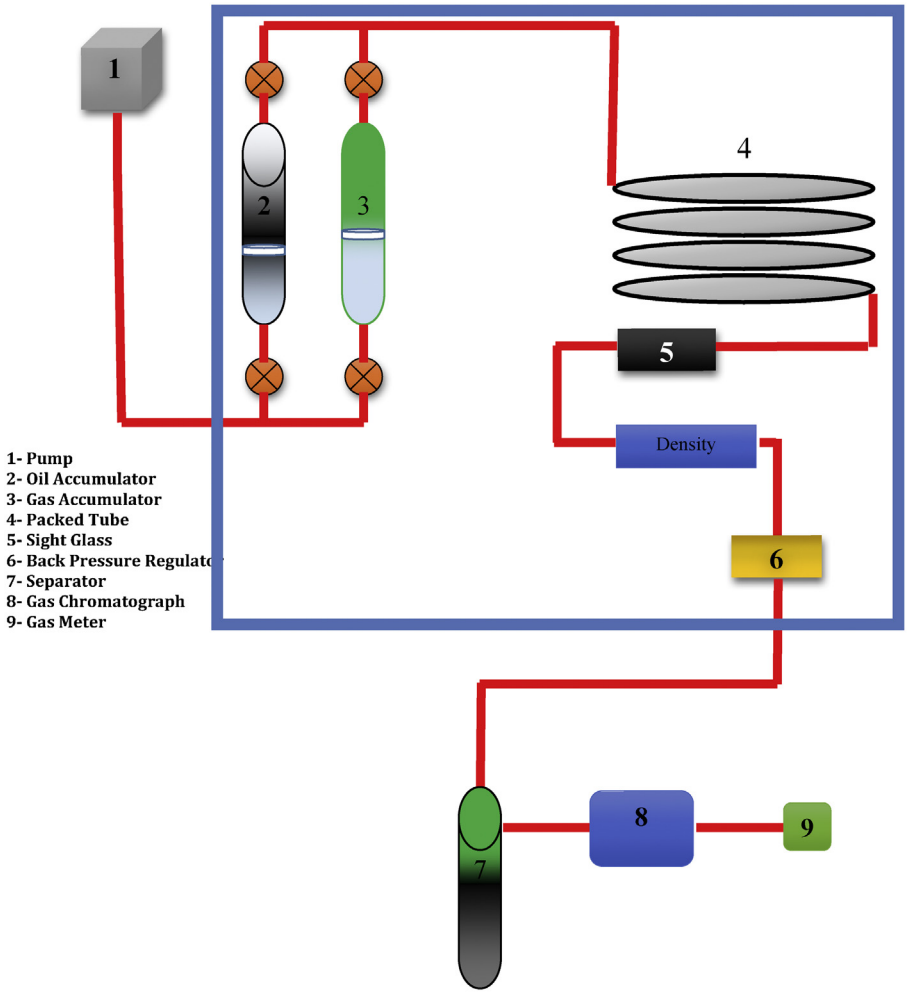

Fig. 1. Graphical scheme of the slim tube apparatus.