ANALYSIS OF EXPERIMENTAL METHODS FOR PREDICTING MINIMUM MISCIBILITY PRESSURES IN OIL.

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Abstract: This article aims to carry out a literature review of the different experimental methods for determining MMP, presenting a comparative analysis between slimtube, rising-bubble (RBA) and coreflood. Each experimental method was evaluated and understood. A critical analysis was performed from design, operation and application to the parameters in each method. Because it is visual, the RBA allows more precision and repeatability than the slim tube and coreflood, because it has fewer differences between their experimental designs. In addition, when dealing with the experiment time factor, the RBA is also superior to the other methods, taking hours to determine the MMP.

Keywords: slim tube; coreflood; rising-bubble; RBA; MMP.

ANÁLISES DOS MÉTODOS EXPERIMENTAIS DE PREDIÇÃO DAS PRESSÕES MÍNIMAS DE MISCIBILIDADE NO ÓLEO.

Resumo: Este artigo tem como objetivo realizar uma revisão bibliográfica dos diferentes métodos experimentais de determinação de MMP e realizar uma análise comparativa entre slimtube, rising-bubble (RBA) e coreflood. Cada método experimental foi avaliado e entendido. Foi realizado uma análise crítica que engloba desde o design, funcionamento e aplicação, aos parâmetros considerados em cada método. Por ser visual, o RBA permite mais precisão e repetitividade que o slim tube e o coreflood por possuir menor diferenças entres os seus designs experimentais. Além disso, ao se tratar do fator tempo de experimento, o RBA também se mostra superior aos demais métodos, levando horas para a determinação da MMP.

Palavras-chave: slim tube; coreflood; rising-bubble; RBA; MMP.

1. INTRODUCTION

To maximize the oil production in mature reservoirs that does not have satisfactory results with the secondary recovery, the Enhanced Oil Recovery (EOR) are applied. Among them, the miscible gas injection has proven to be one of the most effective methods. The natural gas, nitrogen and carbon dioxide are examples which can be used in this injection and the success of these projects have a strong connection with some parameters [1, 2].

One of the most important parameters in this study is the minimum miscibility pressure (MMP), which can be defined as the limit pressure to reach the miscibility in situ between the injection gas and reservoir oil. Also, it is necessary to operate close to this limit and acquire the biggest oil recoveries from the reservoir's injections [1].

The measurement of this MMP can occur through several empirical correlations that aims to predict these values, adjusting the data obtained experimentally to the factors that interfere it, such as: impurities contained in the injected gases, oil temperature or its composition [3]. The MMP usually is measured by the laboratory methods, and they are considered by the literature an accurate way to determine it. Among these experimental methods, the most applied in the oil industry are slimtube, rising-bubble (RBA) and gas injection into rock cores in coreflood type apparatus [1-3].

The experimental methods differ in two main categories: the first one refers to how the information can be obtained, like non-visual and visual way. Currently, non-visually measured data are collected from conventional displacement tests in porous environment. This medium is artificially formed by glass or sand spheres (which resemble the composition of a siliciclastic reservoir), packaged into the slimtube tubes and/or in a coreholder. Regarding the visual means, to determine MMP is usually through tests without porous media, containing only fluid that allows the flow and visualization of the injected gas, as is the example of the rising-bubble apparatus (RBA) [4].

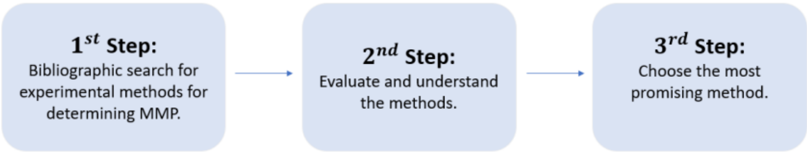
This article aims to present literature review of the different experimental methods for determining MMP, compare and analyze them.

2. METHODOLOGY

This article presents a literature review the most used experimentally methods to measure the minimum miscibility pressure.

Each experimental method was evaluated and understood. A critical analysis was performed, since the design, operation, application, and all parameters considered in each method. Then, a comparative analysis was performed between the selected experimental methods to determine the promising method, according to the block diagram in Figure 1.

Figure 1. Description of literature research methodology.



3. RESULTS AND DISCUSSION

This section presents a brief literature review of three experimental methods to measure the minimum miscibility pressure. These techniques are split into visual and non-visual experimental methods, with the slim tube and coreflood as examples of non-visual methods and the rising bubble apparatus (RBA) as an example of visual methods.

3.1 Slim tube

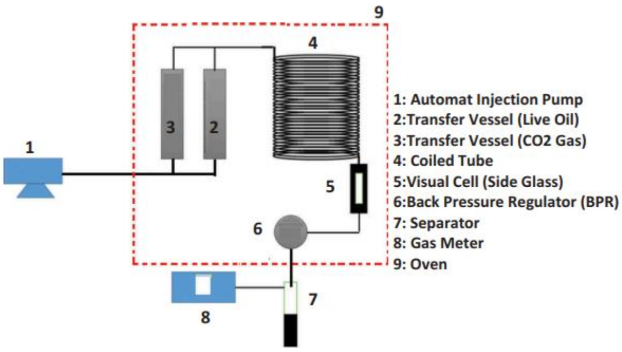
The slim tube is often defined in the literature as the standard test to measure the minimum miscibility pressure. The experimental apparatus is composed of a porous medium that contain glass or sand spheres, which represents the reservoir in a one-dimensional way. This environment exists in a coiled tube of approximately 18 m length, with an average diameter of 0.5 cm, as seen in Figure 2 [4,5].

Despite being a famous equipment, the slim tube does not have a standardization regarding the length or diameter of the coiled tube, varying from each machinery. The variations of the first parameter, can occur between 2 and 40m and the second one can be from 0.1 to 1 cm [3-5].

The porous medium can also change and generate some incompatibilities and uncertainties during the determination of the minimum miscibility pressure. These unclear results usually occur due to an oscillation of the gnocchi DI, that directly interferes with the development of miscibility, axial dispersion, viscosity management and gravity overlap. While the variation in length affects the formation of transition zones [3-5].

Initially, the coiled tube is saturated with an oil sample (liquid phase), then it is heated and maintained at the temperature of the reservoir of interest and its pressure adjusted to a higher one compared to the bubble point. Then the gaseous solvent is inserted at a constant pressure, generating an oil displacement present in the coiled [4].

Figure 2. Schematic of slim tube apparatus [5].



Miscibility conditions are determined from rearrangement under various conditions, always monitoring equipment recovery. From the obtained data, a curvature as a function of displacement pressure is plotted, as can be seen in Figure 3 [4-6].

Figure 3. Determination of MMP.

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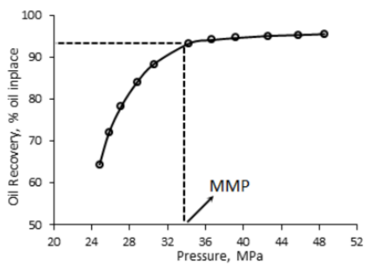

Performing this test is considered time-consuming by researchers, requiring about 4 to 5 weeks to determine a single MMP value. Another issue of the slim tube is the presence of asphaltenes in the oil, which can precipitate and even block the tube, increasing the displacement pressure and sometimes completely blocking the pipeline, making it impossible to conduct the experiment. [3].

3.2 Coreflood

Like the slim tube, the coreflood is also a non-visual method and has a similar operation, in addition to the equipment design, for the determination of MMP. Differentiating in the dimensions of the porous medium that will be applied in the displacement. The scheme representing the method is shown in Figure 4. The coreflood has an advantage over the slim tube as it uses real cores from the analyzed reservoirs and reaches the saturation of the connate water before the gas injection [4].

Figure 4. Coreflood method diagram [4]

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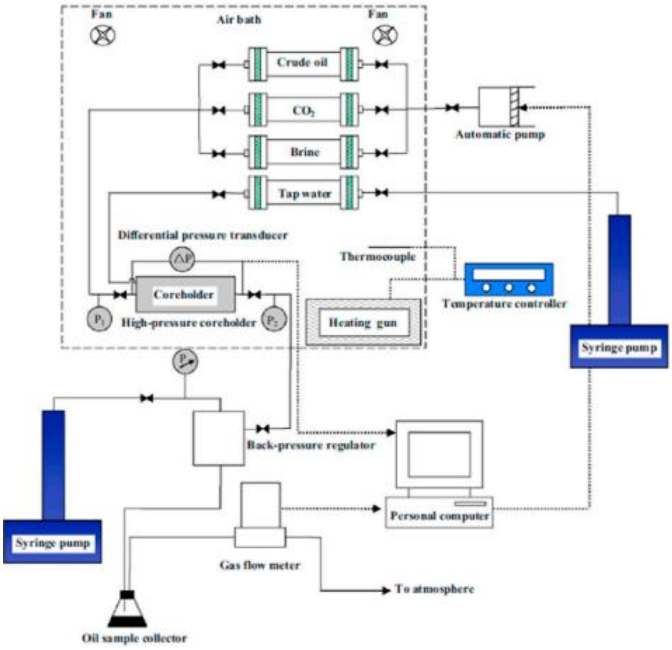

Cores from real reservoirs contain a lot of contamination, the preparation step before each test is superior to the slim tube, as they need to be completely clean, being a disadvantage of the method when considering the time factor. It takes approximately 4 months to determine a single MMP value from the results of five injection tests. And as mentioned above, the determination criteria are the same as for the slim tube [4].

Results obtained through coreflood indicate that an almost miscible injection displaces and mobilizes the oil in a similar way to miscible injections. It is also a good alternative for increasing oil recovery in the vicinity of the MMP [7].

3.3 Rising Bubble Apparatus (RBA)

Different from the other two methods mentioned above, RBA is a visual method. This takes place through a plan glass vertically situated in a high-pressure display, controlling its temperature through a bath. There is a backlight to observe and photograph the bubbles in the oil. Gas injection occurs by a hollow needle, located at the bottom of the display. Figure 5 demonstrates a distinctive design of this glass, responsible to allow the one-dimensional flow of the experiment [3].

Figure 5. RBA diagram [3]

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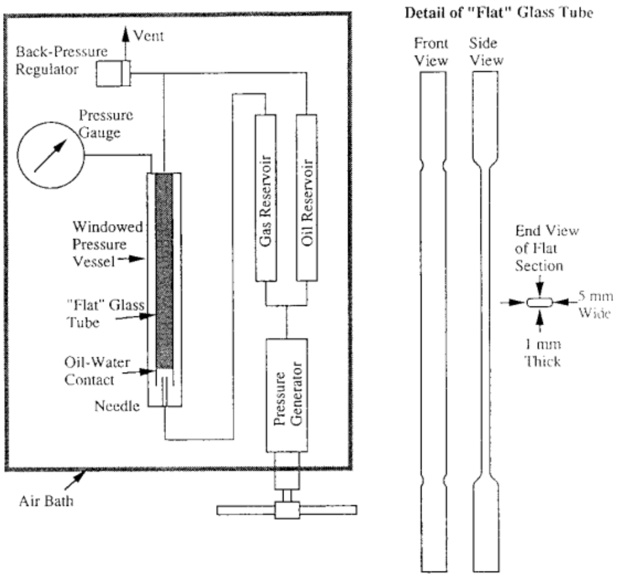
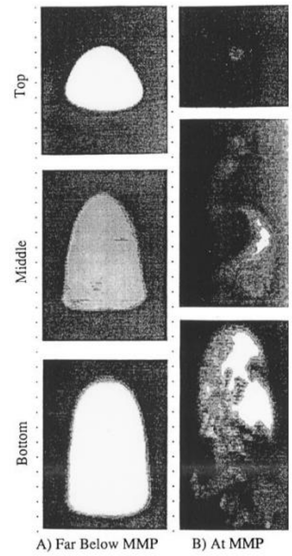


The test starts filling the glass tube with distilled water and injecting the oil sample, displacing pre-existing $H2O$ except for a small column at the bottom, as shown in Figure 5. Subsequently, a small bubble of gas is inserted into the water, rising to the water-oil interface. As it rises, observes the shape and movement, being photographed for further analysis. After the bubble travels the entire length of the glass tube, a new aliquot of oil is placed, following the previous procedures, and a new test is performed at a different injection gas pressure or composition [3].

The behavior of the bubble can be seen in Figure 6, which is possible to see the influence of pressure on the shape and movement of the gas. It is important to notice that at first there is a defined formation of the bubble, while the pressure is lower than the MMP. However, with the increase of this pressure, a behavior change of this bubble happens, and its presence at the end of the glass tube is imperceptible. This indicates the occurrence of miscibility between the two phases, allowing us to affirm that the MMP is found there. This occurs from the dramatic reduction in interfacial tension and the decrease in the interface between the gas and the oil phase as the pressure increases above the MMP. [7].

Figure 6. Gas behavior in the RBA at different pressures [3].



It is important to emphasize that the determination of the minimum miscibility pressure takes place in hours, because the RBA and the precipitation of asphaltenes is not harmful since only stains on the walls of the tube are noticed, without relevant interference in the photographs of the behavior of the injected gas. Considering a small glass tube, a smaller amount of oil sample is needed to conduct the experiments when compared to non-visual tests. [3].

4. CONCLUSION

From the studied analyzes, it is possible to affirm that, despite not being considered the industry standard for determine the minimum miscibility pressure, RBA method has advantages in comparison with the other two selected methods. The visual behavior allows more precision and repeatability than the slim tube and the coreflood, due to fewer differences between their experimental designs. In addition, when dealing with the experiment time factor, the RBA is also superior to the other methods, taking hours to determine the MMP. Another limitation overcome is the possibility of precipitation of asphaltenes, because even if spots are visible, the behavior of the bubble can still be observed.

It is important to emphasize that this study is in its initial phase, so to confirm the conclusions stated above, it is necessary to have more depth in relation to other experimental methods turning possible to affirm that in fact the RBA is superior to the others. This survey will continue in later works.

Acknowledgments

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