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Numerical Prediction of the Impact of Porosity on the Flow Behavior of Two Immiscible Fluids Within a Porous Medium

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ABSTRACT

The extraction and refinement of oil and gas are important in meeting global energy demands, particularly when compared to alternative energy production methods. In order to address the worldwide energy demand, it is imperative to augment both oil reserves and production capability. This objective can be achieved through the development of established reservoirs or the identification of previously undiscovered reservoirs. Enhanced Oil Recovery (EOR) approaches pertain to the utilization of advanced technologies that have been created to augment the extraction of hydrocarbons after primary and secondary recovery methods. Water injection has been recognized as a significant prospective remedy for addressing numerous issues encountered throughout the different stages of hydrocarbon extraction. The objective of the present investigation is to examine the impact of porosity and permeability on the fluid flow behavior of two immiscible Newtonian fluids within a porous media. In this study, the researchers also considered the impact of changes in the Reynolds number. To simulate the movement of immiscible fluids within the soil, we adopt a two-dimensional cylindrical pipe as a representation of the problem's geometry. This pipe is filled with similar particles, which serve to characterize a homogenous porous material. The pipe is initially filled with oil to its maximum capacity. A water flow is introduced at the input to facilitate the displacement of oil towards the producing well. To elucidate the arrangement of immiscible flow within porous and non-porous media, the laminar flow is simulated by employing the Volume of Fluid (VOF) model. Subsequently, the obtained physical outcomes are examined across a broad spectrum of Reynolds numbers. The finite volume approach with ANSYS/Fluent® software was employed to conduct the simulation in an unstable condition. The mathematical and physical models employed in this study have undergone validation by comparison with an experimental database that is accessible in the existing literature.

Keywords : EOR, porous media, Numerical simulation, immiscible, VOF, Pressure drop.

1. Introduction

In this study, to model the movement of immiscible fluids in soils, we assimilated the problem geometry by a two-dimensional cylindrical pipe of diameter 0.12m and length 0.6m. The medium is filled with identical particles of 6mm diameter to characterize a homogeneous porous medium which is initially saturated with oil. A flow of water is injected at the inlet to force the oil in place towards the producing well. The mesh adopted is a structured mesh of quadrilateral elements with a regular pitch and mesh adjustment at well level. Laminar two-phase flow in porous and non-porous media was modeled using the Volume of Fluid (VOF) model, and unsteady flow was numerically predicted using the finite volume method and ANSYS/Fluent® software.

2. Methodology

2.1 Two-phase flow in porous media

Darcy's law applies to the flow of a single fluid phase occupying the entire pore space of the medium. Its extension to the flow of two fluid phases sharing the pore space was proposed in the late 1940s by Leverett [1], in the form: Where is the dynamic viscosity of the fluid phase q, k is the permeability of the medium, is the pressure of the fluid phase, is the density of the fluid and is the relative permeability of the medium as a function of saturation. Two-phase flow in porous media is also described by the continuity equation as a function of each phase's saturation, density and medium porosity ∅, as follows:

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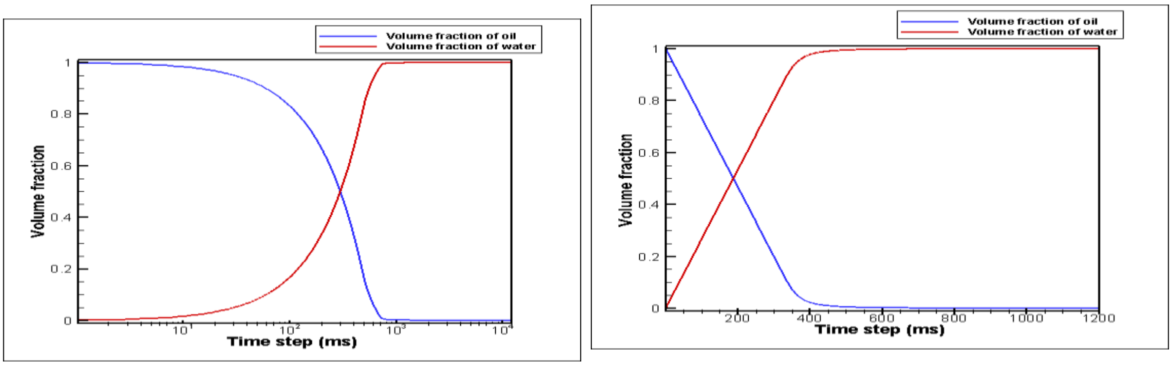
Table 1. *Properties of porous media and fluids* [2]

Properties of porous media	**(mm)**	**Ø (%)**	**K( )**	**η(m)**	**()**
	6	37.5	3.24 x	2.89 x	6913.58
Properties of fluids	Fluid	Dynamic viscosity (kg/m.s)		Volumic mass (kg/)	Tension interfaciale (N/m)
	water	0.001003		998.2	
	oil	0.048		960	

3. Results and discussion

In order to explain the structure of immiscible flow in porous and non-porous media, the physical results are first discussed for a wide range of Re numbers. Assuming Newtonian fluids, incompressible, heavy and with constant physical properties. The simulation was run in unsteady mode, with a convergence criterion of order for all residuals.



(a) (b)

Figure 1: Saturation profiles for a water injection speed of 1 m/s,
(a): non-porous medium, (b) porous medium

(a) (b) (c) (d)

Figure 2: Contour of the volume fraction of water injected into the porous and non-porous media (a): V=14 mm/s Ø = 0% ; (b): V = 14 mm/s , Ø = 37.5 % (c): V = 0.1 m/s , Ø = 0% ; (d): V = 0.1 m/s , Ø = 37.5 %

4. Conclusion

From this study, we can see that The visualization of the flow of two immiscible fluids (Fig.2) shows the appearance of the phenomenon of underride displacement, which occurs in both media because the density of the displacing fluid (water) is greater than that of the displaced fluid (oil). A viscous digitation instability that appears in the form of water fingers penetrating oil (Fig.2), known as Saffman-Taylor fingers (1958) [3]. The shape of these fingers depends on system geometry, fluid properties and flow (Toussaint et al. 2004), which has led to the difference in contours between porous and non-porous media.

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