THE USE OF COMPUTATIONAL FLUID DYNAMIC (CFD) IN MODELING WATER/OIL INTERFACE IN ENHANCED OIL RECOVERY (EOR)

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The displacement of one fluid by another immiscible fluid in porous media is an important phenomenon that is frequently encountered in many engineering fields such as soil mechanics, agriculture engineering, ground water and hydrology, and petroleum engineering. Particular examples of the current scientific interest are processes associated with Enhanced Oil Recovery (EOR). To most engineers and scientists, EOR refers to any recovery process that depends on the provision of additional energy to improve the oil recovery efficiency. Two basic problems limit the recovery of oil from a reservoir. The most obvious one is the difficulty of making the oil mobile (displacement efficiency) and the second one is that even when 100% of the oil is made mobile, there is still the problem of how to displace this oil efficiently (sweep efficiency). For the second case, the oil recovery is a strong function of the progress of the front between the displacing phase (water) and the displaced phase (oil). Unstable displacement process occurs when an oil is displaced by less viscous fluid (water). As a result of this instability, a viscous fingering is formed.

In the current investigation, water injection process has been simulated experimentally and theoretically (CFD) to establish the viscous fingering.

For the experimental investigation, a physical model (an experimental rig) has been designed and constructed to simulate the water injection in Enhanced Oil recovery. This includes an injection system, data logging unit, sandpack, and a production system. Conductivity probes have been introduced within the sandpack to detect the interface. Moreover a high speed camera has been used to produce the images of the water/oil interface.

Regarding the theoretical part, a Computational Fluids Dynamics (CFD) models using Phoenics CFD package have been developed and compared with the produced experimental data for the purpose of model validation.

Phoenics solves single-phase fluid flow problems that can be describes by a differential equation of the form,

$$\frac{\partial(\rho\phi)}{\partial t} + \nabla(\rho\phi V) - \nabla(\Gamma_{\phi}\nabla_{\phi}) = S_{\phi} \qquad 1$$

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Transient + Convection - diffusion = source

Transient + Convection - diffusion +

A special version of PHOENICS called Scalar Equation Method (SEM) has been used to model and detect the water/oil interface position. It uses the value of a scalar property of the penetrating fluid as a marker. SURN variable has been introduced to imply the following:

SURN = 1.00	water
SURN = 0	Oil
SURN = 0-1.0	Mixture

The results of both experimental work and CFD modeling are presented through Figures 5 to 12 (attached). A reasonable match has been achieved between the CFD results and those obtained using the experimental techniques (Conductivity probes and camera's images). The advancement of the water/oil interface is dramatically affected by the viscosity and permeability of both the displacing and the displaced phases. It has also been concluded that CFD can be a useful tool in predicting viscous fingering phenomenon in this particular context and for general free surface engineering problems modeling.

KEYWORDS: CFD, EOR, Water injection, viscous fingering, porous media.

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