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Effects of Wettability and Permeability on Viscous Fingering during Unstable Immiscible Displacements

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During water flooding of viscous oil reservoirs, adverse mobility ratio leads to an unstable displacement and thus viscous fingering. Previous research in viscous fingering has focused on low flow rates and high permeability systems (above 1 Darcy). This paper provides a more thorough and systematic study of the factors affecting viscous fingering including lower permeability, different wettability and high flow rate. Homogeneous cores with permeability ranging from 20 md to 6 Darcy are selected for unstable coreflood experiments. For water-wet systems, water is used to displace viscous mineral oil of different viscosity. For weakly oil-wet (mixed-wet) systems, the core is aged in a crude oil and water displaces a viscous oil. To study strongly oil-wet system, the fluid phases are switched. A light hydrocarbon is used to displace a viscous water in a water-wet core, which is invasion of a strongly non-wetting fluid (similar to water invasion in an oil-wet rock). The effects of permeability, wettability and flow rate on fingering and oil recovery are studied. Unstable displacements are also conducted in micromodels to allow easy visualization of pore-scale mechanisms.

For water-wet systems, decreasing permeability leads to more intense fingering and lower recovery. Increasing flow rate leads to consistently lower recovery due to less time for the imbibition of water into oil-filled pores. $Nvf = Nc\ (\mu r^2)\ (D^2)/K$ can be used to correlate recovery in the presence of viscous finger for water-wet systems. Weakly oil-wet (mixed-wet) systems show distinctly different flow patterns than strongly oil-wet and water-wet systems. For strongly oil-wet systems, permeability does not have a significant effect on fingering and recovery. At low flow rates, increasing flow rate leads to a higher recovery because the higher pressure in the finger can overcome the capillary pressure and invade oil-filled pores. However, further increase in flow rate enhances fingering and results in lower recovery. There exists an optimum flow rate to yield the highest recovery in strongly oil-wet systems. $Nvs=[Nc^{(-1)}]\ \mu_r^2\ D^2$ can be used to correlate recovery in the presence of viscous finger for strongly oil-wet system. Viscous fingering is more intense in oil-wet systems than in water-wet systems. Water film flow in water-wet systems damps viscous fingering, but there is little oil film flow in strongly oil-wet systems due to the high oil viscosity.

References

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