INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Investigation of Multiphase Flow in Porous Micromodels using Micro-PIV Experiments and Numerical Simulations.

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SHORT ABSTRACT

This study investigated pore-scale flow dynamics and displacement mechanisms in multiphase flow through porous media using experimental and numerical approaches. 2D porous micromodels of various geometries were fabricated to visualize the fluid flow using Micro-Particle Image Velocimetry. Parameters such as displacing phase flow rate, viscosity, heterogeneity of porous medium, interfacial tension, and wettability were found to significantly impact the trapping and mobilization of the non-wetting phase through the porous medium. Chemical slugs (including alkaline solution, polymer solution, and alkali polymer solution) and nanoparticles (silica) improved fluid-fluid and fluid-solid interactions. Silica nanoparticles in an alkaline solution enhanced oil mobilization by reducing the interfacial tension, altering the contact angle, and preparing a stable microemulsion. The parameters such as flow rate and viscosity affected the displacement, showing the shear-induced circulations, viscous instability, droplet breakage, and coalescence, resulting in unsteady flow behavior during immiscible two-phase flow in heterogeneous micromodels. Higher flow rates reduced trapped fluid saturation but intensified shear-induced circulations. Heterogeneous micromodels exhibited more trapping than homogeneous porous medium. Numerical simulations focused on the immiscible two-phase flow in complex pores (such as dead-ends and contraction-expansion pores), highlighting the impact of injection velocity, viscosity ratio, interfacial tension, wettability, trapped oil viscosity, and geometric parameters. Lower contact angles had minimal effect on residual oil saturation until reaching a critical contact angle. Complete displacement from the dead-end occurred when the oil-water interface reached the dead-end bottom before the rupture point. Higher injection velocities improved oil recovery from the dead-ends, while lower velocities enhanced recovery from the contraction-expansion pores. Microscopic studies used 2D micromodels to explore displacement and oil recovery during low-salinity water flooding and subsequent chemical floodings. The observed phenomena included fluctuating flow, flow direction reversal, viscous fingering, film formation, unsteady behavior, and velocity jumps during low salinity water flooding. Polymer flooding had a limited impact on the trapped oil, while the alkali-polymer solution injection enhanced oil recovery through emulsification, interfacial tension reduction, and increased water-wettability. The core flooding experiments demonstrated an overall heavy oil recovery of 75.37% with simultaneous chemical slug injection, whereas individual slug injections resulted in lower oil recovery, particularly for alkali-surfactant-polymer flooding. Porous micromodels elucidated suspension flow dynamics, revealing the influence of initial particle location, concentration, and shear-induced particle migration.