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Pore-scale visualization of emulsion flow in linear and radial microfluidic porous media

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Pore-blocking efficiency is a key factor when dilute and stable emulsions are used as flow diversion agents to increase oil recovery and reduce water mobility in preferential flow paths. Emulsion plugging occurs when droplets of the dispersed phase are trapped in the pore throats as they flow through porous media. The droplet capture phenomenon is highly dependent on the drop-to-pore size ratio, the dispersed phase concentration, and the capillary number. Therefore, understanding the transport of droplets and the physical mechanisms of pore-blocking at the micro-scale is fundamental for a proper design of emulsion flooding as an enhanced oil recovery (EOR) method. The performance of oil-in-water (O/W) emulsions as pore-blocking agents was investigated by studying the transport of oil droplets through transparent porous media. To this end, a 2D PDMS/glass porous media micromodel with varying constriction sizes was used. O/W emulsion systems with two distinct drop size distributions were formulated to conduct the tests at different capillary numbers. The tests were performed by recording the injection pressure response during the sequential flow of an aqueous phase, followed by emulsion (oil drops dispersed in the aqueous phase) and then by a second slug of the aqueous phase. The association of microfluidic devices and imaging techniques provided a robust methodology, combining accurate pressure measurements and pore-scale visualization of the droplets'capture phenomenon during emulsion flooding. Detailed visualization of the flow was achieved by high-speed image acquisition at different stages of the test to identify the droplets'capture mechanisms and their capture/release dynamic in the pore throats. Droplets larger than the pore constrictions were captured by the straining mechanism, while the smaller ones were adsorbed on the pore walls, blocking the flow paths by droplet accumulation (bridging). At low capillary numbers, a larger number of droplets were captured in the pore throats because of the stronger capillary forces. As the capillary number was increased above a threshold value, the viscous force was large enough to overcome the capillary resistance and the droplets were able to deform and re-enter the flow stream. This behavior was quantitatively demonstrated by comparing the mobility of the emulsion to that of the aqueous phase. Finally, a pore-scale visualization study was also conducted in a radial porous media micromodel to evaluate the performance of emulsion flooding with varying capillary numbers. The relationship between mobility control and the capillary number was investigated aiming to define the desired location of the pore-blocking.

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Participation

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References

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Primary authors: DE AMORIM, Clarice (PUC-Rio); DA COSTA E SILVA DE NORONHA PESSOA, Amanda; PONCE F., Ranena V. (PUC-Rio); CARVALHO, Marcio (PUC-Rio)

Presenter: DE AMORIM, Clarice (PUC-Rio)

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