Enhanced Oil Recovery by Analysis and Control of Vortex Flow in Porous Media

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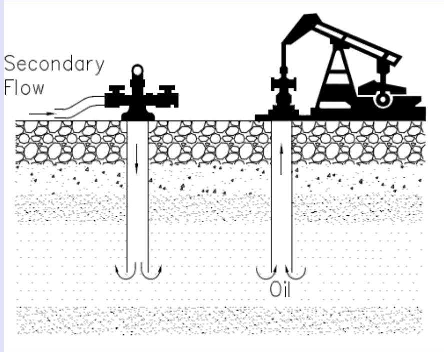
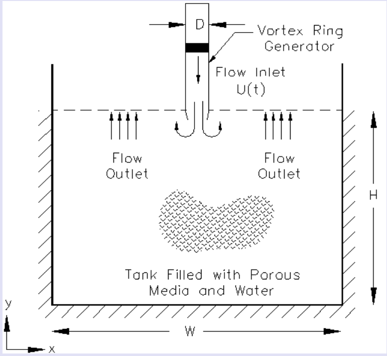
Analysis of vortex flow through permeable (porous) media are essential for a thorough analysis of many natural and man-made processes. An example is the injection of a secondary flow underground to drive more oil to a production well. The secondary flow is generated by water, steam, or carbon monoxide that is injected by a pump through a secondary well. Although this process, also known as ``flooding,'' has been known for some time, it is far from perfect. Our preliminary simulations have indicated that pumping creates vortex flows in the porous underground layers. The proposed research aims to expand on this new insight and develop a detailed analysis of vortex flows in porous media, leading to a new understanding of the pattern of underground flows. This research focuses on the fundamental scientific questions that naturally arise from investigating underground vortex flows, namely uncovering the effect of (a) porosity, (b) permeability, (c) secondary fluid density and viscosity, (d) injection velocity, pressure, pulse duration, and frequency, and (e) injecting well dimension, on the behavior of fluid pattern separation, accumulation, and transport phenomena of the oil flow within the underground layers. Research is being conducted through both simulation and experimental work.

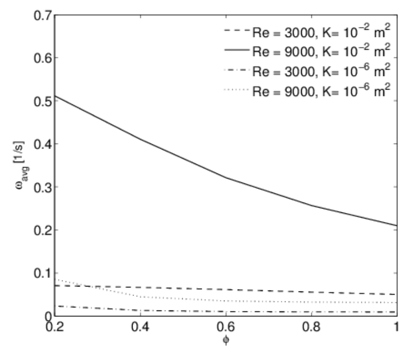


<u>Outcomes of Numerical Analyses:</u>

1. Vortices can display interesting behaviors while interacting with a porous obstacle, and that their behavior depends on physical properties such as permeability and the impingement velocity.
2. Among these properties, permeability has the dominant effect on the flow pattern formation. The impingement velocity has a noticeable effect on the formation and progression of vortex pairs only for low porosity and high permeability domains.
3. The magnitude of the average vorticity was calculated for a wide spectrum of porosities and permeabilities. The results show that the average vorticity increases as the permeability increases but that it remains almost constant after a threshold. For media with low permeability however, average vorticity remains constant for a range of permeabilities and starts to weaken until it becomes zero after a low point.
4. The contribution of vortices formed inside the voids in the porous medium leads to a higher overall value for vorticity. Consequently, we find a high correlation between an increase in average empty space in the solid constituent (porosity) and the increase in the overall vorticity.



Schematic configuration of the 2-D model



Variation of average vorticity vs. porosity