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Transition from Hele-Shaw Flow to 2-D Creeping Flow
JOHN CIMBALA, Penn State, MANOOCHEHR KOOCHESFAHANI, Michigan State — In the Hele-Shaw experimental technique, liquid flows at very low Reynolds number through the narrow gap $b$ between parallel plates. When a body is inserted between the plates, and dye is introduced upstream, the streaklines appear nearly identical to streamlines of steady 2-D potential flow over a body of the same shape. For example, Hele-Shaw flow does not separate at sharp corners, just like potential flow. However, if the plates are very far apart (large $b$), the resulting creeping flow at the same low Reynolds number is observed to separate at sharp corners, unlike potential flow. Here, we investigate how the flow changes from Hele-Shaw flow (small $b$) to 2-D creeping flow (large $b$). Low Reynolds number CFD simulations of a fence of height $s$ along a wall in a channel reveal that the transition from Hele-Shaw flow to 2-D creeping flow is not sudden, but rather quite gradual as channel gap width is increased. Separation bubbles appear at small $b/s$, and grow in size as $b/s$ increases. The reattachment length reaches 1% of the 2-D value at $b/s \approx 0.21$, but it does not reach 99% of the 2-D value until $b/s \approx 150$. Furthermore, for all values of $b/s$ for which separation and reattachment are observed, even for large $b/s (> 100)$, the reattachment length of the separation bubble is non-uniform across the span; it starts high, dips to a minimum, and then slowly rises, reaching 99% of the center plane value beyond about 15s to 20s from the wall.

John Cimbala
Penn State

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