71b Transport of Ultrafine Particles in Bifurcations

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The transport of ultrafine particles in human airways is of great importance to health risk assessments and pulmonary drug delivery. The dominant deposition mechanism of ultrafine particles is Brownian diffusion, as opposed to inertial impaction and sedimentation for larger particles. Hence, for ultrafine particles, an adequate description of the deposition can be obtained from solutions to the fluid momentum equations and the convective diffusion equation. Preliminary numerical(FEMLAB) studies on a 2-D single bifurcation have been conducted by invoking order of magnitude arguments at high Schmidt numbers. The results have demonstrated the functional dependence of global Sherwood numbers on Strouhal number and the diffusive analogue of the Womersley number. High Schmidt numbers lead to the development of thin concentration boundary layers near the leading edge of the carinal ridge, and the resulting mass transfer can be adequately described by the Leveque approximation.

At higher Reynolds numbers, separation may be expected at the outer walls of the bifurcation; and predictions based on a 3-D numerical solution of the momentum equations confirm this expectation. Separation can, in turn, lead to the interesting phenomenon of increasing mass transfer with increasing axial distance. In addition, the extension to a double bifurcation model reveals a reversal in the secondary vortex sense in the grand-daughter branches at some critical Reynolds number. The aerosol concentration profiles also show interesting developments such as the emergence of a swirling concentration wake downstream of the separation region. This demonstrates a strong interplay between the transport phenomena in consecutive generations such that the predictions based on a single bifurcation may be inaccurate. The development of complex secondary flows has major implications for the mass deposition profiles. The intersecting secondary vortices create regions of high wall mass flux that are not necessarily in the vicinity of the carinal ridge.