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DIFFUSIVE FLUX MODELING OF RBC TRANSPORT DURING BLOOD FLOW IN MICROCHANNELS

Rishi Kumar*, Indranil Saha Dalal* and K. Muralidhar**§
*Department of Chemical Engineering, IIT Kanpur India
**Department of Mechanical Engineering, IIT Kanpur India
§Corresponding author. Fax +91 512 679 7048 Email: kmurli@iitk.ac.in

ABSTRACT

The most significant constituent of blood are disk-shaped red blood cells, around 8 microns in size, occupying up to 40% of the total fluid volume. In arteries of 10 mm diameter or higher, an effective viscosity that scales with RBC concentration is applicable. In smaller diameter vessels, however, unexpected phenomena, for example, the Fahraeus effect, are revealed and call for an independent approach to modeling. The diffusive flux model that includes shear-driven migration is one such route of interest here and enables treatment of particulates in blood within a computational fluid dynamics framework. The distribution of the RBC volume fraction, namely, hematocrit is obtained by solving a nonlinear particle transport equation formulated using the diffusive flux model. The momentum and hematocrit transport equations are coupled through a hematocrit-dependent viscosity expression tailored for blood. The coupled equations are numerically solved by a 3D unstructured finite volume method. Three geometries with sizes of the order of 40 microns have been considered. For flow in a tube, concentration distribution and the thickness of the cell-free layer from the proposed model show a good match with experiments. For flow inside a tube with a constriction, hematocrit depletion is found to be greater downstream of the neck, in agreement with meso-scale simulations. For a branched tube, the average hematocrit concentration is found to be higher for the branch with the higher flow rate, thereby complying with the Zweifach-Fung bifurcation law. An application of this result for platelet separation on a laboratory-scale is demonstrated.

BIOGRAPHY

Dr. K. Muralidhar is Professor of Mechanical Engineering at Indian Institute of Technology Kanpur (India) where he has worked since 1987. He has a PhD from University of Delaware (1985) with postdoctoral research experience at Lawrence Berkeley Laboratory, USA. He has conducted a wide range of experiments and performed numerical simulation in subjects related to fluid mechanics and heat transfer. His work has led to better understanding of intermediate Reynolds number jets and wakes, transport phenomena during growth of optical crystals, dropwise condensation over textured surfaces, and biomedical imaging of intracranial aneurysms. His ongoing research interests include liquid-vapor interfacial phenomena and phase change, contact line dynamics, mechanistic modeling of disease progression and blood rheology. He is presently coordinating an institute-level initiative on developing a left ventricular assist device that will pave way for a total artificial heart.

Over one hundred and seventy publications arising from this research have been published in well-known international journals and eight patents granted. He is the author of nine books including monographs on droplet dynamics and dropwise condensation and schlieren and shadowgraph imaging. He is the editor-in-chief of the Journal of Flow Visualization and Image Processing. He a Fellow of the Indian National Academy of Engineering, National Academy of Sciences, and the American Society for Thermal and Fluid Engineers.