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Numerical Analysis of Core-Annular Blood Flow in Microvessels at Low Reynolds Numbers

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Abstract : In microvessels, red blood cells (RBCs) exhibit a tendency to migrate towards the vessel center, establishing a core-annular flow pattern. The core region, marked by a high concentration of RBCs, is governed by significantly non-Newtonian viscosity. Conversely, the annular layer, composed of cell-free plasma, is characterized by Newtonian low viscosity. This property enables the plasma layer to act as a lubricant for the vessel walls, efficiently reducing resistance to the movement of blood cells. In this study, we investigate the factors influencing blood flow in microvessels and the thickness of the annular plasma layer using a non-miscible fluids approach in a 2D axisymmetric geometry. The governing equations of an incompressible unsteady flow are solved numerically through the Volume of Fluid (VOF) method to track the interface between the two immiscible fluids. To model blood viscosity in the core region, we adopt the Quemada constitutive law which is accurately captures the shear-thinning blood rheology over a wide range of shear rates. Our results are then compared to an established theoretical approach under identical flow conditions, particularly concerning the radial velocity profile and the thickness of the annular plasma layer. The simulation findings for low Reynolds numbers, demonstrate a notable agreement with the theoretical solution, emphasizing the pivotal role of blood's rheological properties in the core region in determining the thickness of the annular plasma layer.

Keywords : core-annular flows, microvessels, Quemada model, plasma layer thickness, volume of fluid method
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