22f Pulsatile Flow and Gas Transport over an Array of Cylinders: Gas Transfer Model inside an Artificial Lung

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In the artificial lung device, blood passes through an array of micro-fibers and the gas transfer is strongly dependent on the flow field. For an implantable artificial lung device which is driven by the heart, the flow is unsteady and pulsatile. We have numerically simulated pulsatile flow of both Newtonian and Casson fluids over arrays of micro-porous fibers modeled as hollow cylinders. The unsteady gas transport of both a passive fluid (Newtonian) and a fluid with hemoglobin (blood, Casson) are modeled and computed. Oxygen and carbon dioxide are assumed to be in local equilibrium with hemoglobin in blood; and the carbon dioxide facilitated oxygen transport is incorporated into the model by allowing the coupling of carbon dioxide partial pressure and the oxygen saturation. The pulsatility flow inputs considered are the sinusoidal waveform and the cardiac waveform. Different arrangements of the cylinders: squared array, and staggered array are considered in this study. Depends on the system parameter values, gas transfer is enhanced by unsteady inertia and vortex dynamics. In general, gas transport is found to be better for the staggered array geometry which has a wider spacing between the cylinders in the average flow direction. The gas transport can also be improved by: increasing the oscillation frequency; increasing the Reynolds number; increasing the oscillation amplitude; decreasing the void fraction; the use of the cardiac pulsatile input. The overall oxygen transport is greatly enhanced by the presence of hemoglobin in blood; although at the same time the non-Newtonian effect of blood tends to decrease the size and strength of vortices. Flow resistance through the array is also presented as it is an important design parameter confronting the heart. Optimizing the array geometry for gas transfer (as high as possible) and for resistance (as low as possible) is an important aim of the study.