Examining the Effect of Red Blood Cell Collisions Using a Fully Eulerian Simulation Approach

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Abstract

Computational fluid dynamics simulations are employed using the volume of fluid multiphase approach to simulate the fluid structure interaction dynamics of red blood cells in a Couette shear flow. A fully Eulerian structural approach is employed using a finite volume solver to simulate the structural dynamics in order to eliminate the need to Re-mesh the fluid portion of the simulation. Transport equations are defined for the components of the Left Cauchy deformation tensor, from which a solid stress is computed and directly incorporated into the momentum equations. Several improvements are made to the standard fully Eulerian approach for fluid structure interaction. A hyper-elastic strain energy function based on the Yeoh Model fit using optical tweezers that enforces area incompressibility is developed to model the higher-order strain stiffening behavior of the red blood cell. Furthermore, a boundary shape function is developed to compute the distance to the membrane and alleviate issues of numerical diffusion associated with the diffusion of the membrane. The method is implemented in ANSYS Fluent, validated, and compared against the simple analytical solutions for a droplet in a Couette shear flow, as well as compared against images of deformed red blood cells in a shear flow. Multiple Simulations are executed to examine the effect of red blood cell packing on the strain induced on nearby cells during collision events. It is found that the traction applied on the red blood cell membrane by the fluid is locally increased by up to a factor of three, and depends on red blood cell packing. There is a noticeable local increase in strain observed due to red blood cell collisions. Please do not exceed one page. Please do not add references or figures to this text-only abstract.