Modeling of blood rheology by modified Immersed Finite Element Method with an adhesive contact mechanics formulation

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Abstract

Modeling blood rheology is aimed at multi-physics interaction problems. Interactions during blood transportation directly influence human metabolism. Fluid-solid interaction(FSI) occurs between plasma and red blood cells(RBC) or blood vessels, while solid-solid interaction(SSI) occurs between cells and vessels. The latter is composed of depletion interactions and electrostatic interactions. It's believed that a better understanding of multi-physical interactions in the hemodynamics will provide crucial insights into blood dysfunctions, like thrombus.

This paper presents a model composed of RBC, plasma, blood vessel with valve. Plasma interacting with RBC and the blood vessel can be achieved by modified-IFEM[(Wang & Zhang, 2013)]. Meanwhile, coarse grained contact model can be used to model the interaction[Fan, Ren, & Li, (2015)], like contact and adhesion between RBC and the blood vessel. We first review m-IFEM formulation and the adhesive contact mechanics formulation. Then, by introducing contact force into the external force term of the hyper-elastic constitutive formulation, the effect of blood flow and adhesive contact on the solids can be considered as boundary conditions. The newly updated solid position and deformation can be used for newly calculating FSI between plasma and the solids. Nevertheless, it may be thought that IFEM have been used to study RBC aggregation[Liu & Liu, (2006)], but in m-IFEM boundary conditions of the solid are generated from the surrounding fluid, and solid mesh distortion can be avoided. Moreover, this paper considered the interaction between plasma and blood vessel with valve, as well as the interaction between RBC and blood vessel with valve. The implementation of the methods is then compared with several cases mentioned in the reference. The results obtained from numerical simulations show good agreements with experimental results.

Keywords: FSI, Coarse Grained Contact, m-IFEM, Blood Rheology

References

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