Model Selection and Coupling in the Context of Biomedical Device Design

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ABSTRACT

Modeling and computational analysis play an increasingly important role in bioengineering, particularly in the design of implantable ventricular assist devices (VAD), coronary stents, and other blood-handling devices. Numerical simulation of blood flow and associated physiological phenomena has the potential to shorten the design cycle and give the designers important insights into causes of blood damage and suboptimal performance.

A set of modeling techniques will be presented which are based on stabilized space-time finite element formulation of the Navier-Stokes equations [1].

In order to obtain quantitative hemolysis prediction, cumulative tensor-based measures of strain experienced by individual blood cells have been developed; red blood cells under shear are modeled as deforming droplets, and their deformation tracked throughout the flow volume. A new log-morphology formulation and its VMS stabilized discretization helps handle strong wall-induced and internal boundary layers [2].

The methods are applied to a benchmark rotary blood pump from an inter-laboratory round-robin study, as well as to current real-life configurations. Increasing the range of biophysical phenomena accounted for in the simulation leads naturally to a strong need for multi-physics and multi-scale coupling and reduction techniques. Examples of such issues arising in the context of a drug-eluting coronary stent simulation will be cited. Here as well, computations often benefit from a tailored change of variables [3].

REFERENCES

[1] L. Pauli and M. Behr, “On Stabilized Space-Time FEM for Anisotropic Meshes: Incompressible Navier-Stokes Equations and Applications to Blood Flow in Medical Devices”, *International Journal for Numerical Methods in Fluids*, **85**, 189–209 (2017).

[2] S. Haßler, L. Pauli, and M. Behr, “The Variational Multiscale Formulation for the Fully-Implicit Log-Morphology Equation as a Tensor-Based Blood Damage Model”, *International Journal for Numerical Methods in Biomedical Engineering*, **35**, e3262 (2019).

[3] S. Haßler, A. Ranno, and M. Behr, “Finite-Element Formulation for Advection-Reaction Equations with Change of Variable and Discontinuity Capturing”, *Computer Methods in Applied Mechanics and Engineering*, **369**, 113171 (2020).