A fluid-structure-scalar-scalar interaction model with application to early atherosclerosis progression

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ABSTRACT

The analysis of fluid-structure-scalar-scalar interaction is a field of intensive studies and plays an important role in hemodynamics, cardiovascular mechanics and disease progression such as atherosclerosis. In this context, the challenge is the coupling of an incompressible flow with a deformable structure undergoing large deformations, where in the scalar transport the migration of key species into the structure is of special interest. Migrated species react and constitute mechanobiological remodelling, change of material behaviour and finally the development of a stenosis. The underlying bio-chemical and mechanical connections in atherosclerosis are not yet fully understood and hence addressed in an interdisciplinary research project.

In this contribution, we present a sequentially staggered fluid-structure-scalar-scalar interaction approach coupling a monolithic fluid-structure interaction with a monolithic scalar-scalar interaction problem [1, 2]. Since the influence of the scalar fields to the fluid-structure interaction problem is assumed to be on a very large time scale, the overall fluid-structure-scalar-scalar interaction system is sufficiently addresses by a sequentially staggered scheme. The two scalar fields reside in the fluid and structure domains, where the scalar field on the fluid domain is transported with the fluid flow and the other is diffusive and bio-chemical reactive [3]. Their interface is modelled as a semi-permeable membrane where the exchange of scalars is diffusion driven. The permeability of the membrane thereby is shear stress dependent and allows for strong regional differences in transport of scalars through the interface. A resulting reactant in the structure domain scalar field finally influences mechanical properties of the structure and induces a slowly advancing volumetric growth [4], leading to a narrowing of the fluid domain and hence to a change of the fluid flow and formation of a stenosis.

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