Analysis and Applied Mathematics Seminar

Multiscale/Multiphysics Coupling Framework for Bioprosthetic Heart Valve Damage

Yue Yu (Lehigh University)

Abstract: Bioprosthetic heart valves (BHVs) are the most popular artificial replacements for diseased valves that mimic the structure of native valves. However, the life span of BHVs remains limited to 10-15 years, and the mechanisms that underlie BHVs failure remain poorly understood. Therefore, developing a unifying mathematical framework which captures material damage phenomena in the fluid-structure interaction environment would be extremely valuable for studying BHVs failure. Specifically, in this framework the computational domain is composed of three subregions: the fluid (blood) , the fracture structure (damaged BHVs) modeled by the recently developed nonlocal (peridynamics) theory, and the undamaged thin structure (undamaged BHVs). These three subregions are numerically coupled to each other with proper interface boundary conditions. In this talk, I will introduce two sub-problems and the corresponding numerical methods we have developed for this multiscale/multiphysics framework. In the first problem the coupling strategy for fluid and thin structure is investigated. This problem presents unique challenge due to the large deformation of BHV leaflets, which causes dramatic changes in the fluid subdomain geometry and difficulties on the traditional conforming coupling methods. To overcome the challenge, the immersogemetric method was developed where the fluid and thin structure are discretized separately and coupled through penalty forces. To ensure the capability of the developed method in modeling BHVs, we have verified and validated this method. In the second problem, we proposed a Neumann-type interface boundary condition for the nonlocal

Monday, November 12 at 4:00 PM in 636 SEO model. In the nonlocal models the Neumann-type boundary conditions should be defined in a nonlocal way, namely, on a region with non-zero volume outside the surface, while in fluid—structure interfaces the hydrodynamic loadings from the fluid side are typically provided on a sharp co-dimension one surface. Therefore, we have shown that our new nonlocal Neumann-type boundary condition provides an approximation of physical boundary conditions on a sharp surface, with an optimal asymptotic convergence rate to the local counter part. Based on this new boundary condition, we have developed a fluid—peridynamics coupling framework without overlapping regions.

Monday, November 12 at 4:00 PM in 636 SEO