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Poroelastic rough surface modeling for fluid-structure-contact interaction

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Fluid-structure interaction (FSI) including contact of submersed elastic structures is of great interest in numerous applications where motion or deformation of the structure and fluid flow are strongly interacting. For such configurations the prevailing roughness of contacting surfaces, which is often magnitudes smaller than the object size itself, has a significant influence on macroscopic effects like leakage, lubrication and friction. Therefore, special focus has to be set on appropriate modeling of the physics between the contacting structures, including the fluid flow and the deformation of the microstructure.

In this contribution we propose an approach where the macroscopic effects of rough surfaces for FSI with contact are modeled via a thin poroelastic layer attached to the structural surface. Herein, the incompressible fluid flow inside the layer is given by a Darcy-based equation volume-coupled to an elastic matrix under finite deformations (see [1]). For large gaps between the contacting surfaces, the fluid is basically described by the incompressible Navier-Stokes equations, as the influence of the porous layer is negligible.

Once the structures approach each other, the challenges are to appropriately formulate the different time-dependent interfaces and coupling conditions on all interfaces. As contact includes topological changes in the fluid domain, a CutFEM approach, where the structural mesh intersects elements of a non interface fitted fluid discretization, is applied. Furthermore, suitable laws for coupling of the incompressible fluid and the poroelastic layer are integrated, which is numerically realized by a Nitsche-based approach (see [2]). To handle the contact between solid and porous layer within a surrounding incompressible fluid, the dual Lagrange multiplier contact formulation is enriched accordingly. Finally, numerical examples which analyze the behavior of the proposed approach for a leakage flow configuration and a non-return valve are presented.

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