A mixed hybrid formulation for 2D poroelasticity with discontinuity

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In the last decades, porous media research focused on applications of geomechanics. This enabled to achieve important goals in many fields of geo-sciences: petroleum engineering (logging technologies, bore hole instability, CO2 sequestration), soil mechanics (instability of slopes, instability of soils under tunneling), durability of materials (moisture transport). In the recent years the focus of the research about porous media is extending to biology. In fact, all the biological tissues are porous media. To understand the behavior of human tissues, it can be extremely helpful to prevent and treat many diseases related to, for example, blood perfusion, bones (osteoporosis), spine (herniation, low back pain). This project focuses on the intervertebral disc (IVD), that, for its properties, must be treated as a porous medium. The presence of damage, such as cracks, faults, and shear bands, can markedly change the physical behavior of the disc and affects his capacities of providing flexibility to the spine and absorbing and transmitting loads. We are developing a model which describes the behavior of a fracture in a 2D porous medium. As measurements in living humans are complex, finite element models have become an important tool of study load distribution in healthy and degenerated disc [2]. The project will zoom into what happens precisely at the crack tip. Near the tip the stresses are elevated above the average stresses. In order to predict propagation and, with that, structural failure, it is necessary to model what happens at the crack tip correctly. Fluid and solid are so strongly coupled that if fluid flow is not predicted in the right way, the model will predict wrong deformations and with that stresses and therefore propagation. The presence of the fluid relaxes the stress but can also cause stress. In our model, the saturated porous media are modeled as a two phase mixture composed of the deforming solid skeleton and the saturating pore fluids. To numerically simulate the interaction of the skeleton with the fluid, the media are modeled as porous continua, in which a representative element volume around any mathematical point in the media is always assumed to contain the solid phase and the fluid phase. It's been developed a mixed hybrid formulation for 2D poroelasticity with discontinuity. This formulation assembles the major properties of the mixed hybrid formulation with Lagrange multipliers [1] (approximation of the fluid flow fulfills the mass conservation equations locally, simultaneously approximations of flows and pressures) and of the Partition of Unity framework [3] [4] (discontinuities and singularities are modeled through local enrichment, continuity along the crack surface is preserved, discontinuities are introduced in a mesh-free way).

References


