The Finite Cell Method for Contact Problems in Solid Mechanics

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The Finite Element Method (FEM) is the state of the art for contact problems in solid mechanics. Some issues remain, however, which render the analysis of such problems far from trivial. The accuracy of the results is determined by the quality of the geometric discretization, i.e. the mesh. For complex geometries, mesh generation is laborious. In the case of contact analyses the modeling effort is further increased since traditional contact algorithms demand for an explicit definition of contact surfaces. During calculation, additional overhead is introduced by search algorithms, which repeatedly check the status of every contact point or surface to impose constraints correctly [1]. In summary, the analysis of geometrically highly complex problems, e.g. self-contacting foams, turns out to be extremely involved.

To overcome these issues, we propose a new approach for contact mechanics using the recently introduced Finite Cell Method (FCM) [2, 3]. The FCM is a fictitious domain approach for high order finite elements (p-FEM). As such, it embeds the physical domain in a simple Cartesian mesh. The original geometry is recovered at the integration level using adaptive methods, which are easy to implement for Cartesian grids.

The proposed contact model is based on the notion of "filling" void areas or gaps with a fictitious contact material. This material formulation is based on the finite strain, hyperelastic Hencky model given by

$$\Psi(\lambda_1, \lambda_2, \lambda_3) = \mu[(\ln \lambda_1)^2 + (\ln \lambda_2)^2 + (\ln \lambda_3)^2] + \frac{\hat{\lambda}}{2} \ln J$$

where

$$\ln J = \ln \lambda_1 + \ln \lambda_2 + \ln \lambda_3$$

and λ_i are principal stretches. μ and $\hat{\lambda}$ are the well known Lamé parameters.

The Hencky model regularizes the Karush-Kuhn-Tucker conditions, with govern the relations between normal distance and reaction forces inside a gap. Here the principal stretches λ_i can be regarded as a normalized gap function.

Since void regions are occupied by contact material, the model contains weak discontinuities. We model these by independently discretizing physical and contact domains. The two meshes are then connected C^0-continously with the help of weakly imposed constraints [4], see Figure 1.

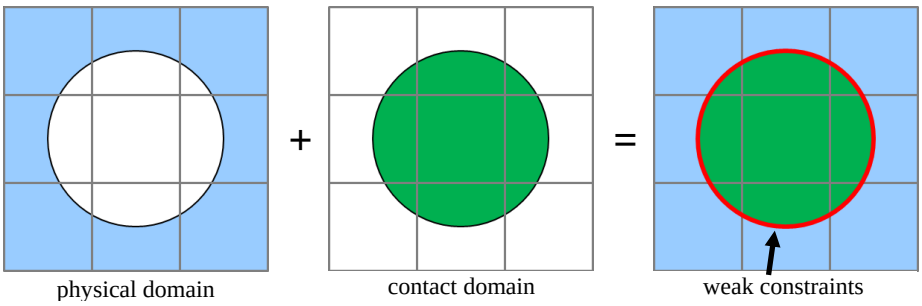

Figure 1: Connection of physical and contact domain

Within the framework of the FCM, this two-mesh approach correctly captures the configurations in both the physical domain and the contact domain without introducing oscillations [5].
This talk will present and discuss the proposed methodology itself with the help of two- and three-dimensional examples.

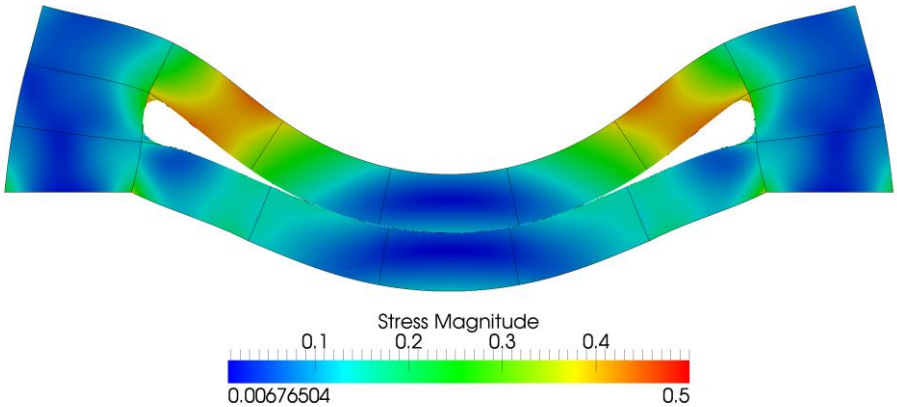

Figure 2: Rectangular block with slotted hole subject to normal traction.

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