11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

THE FINITE CELL METHOD APPLIED TO NONLOCAL DAMAGE MECHANICS

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Key Words: *FCM, Nonlocal Damage Mechanics, High-order FEM.*

As a fictitious domain method, the Finite Cell Method (FCM) has been recently proposed for numerical simulation of a variety of problems in computational mechanics. The outstanding property of this method in comparison with the finite element method is in reducing the cost and time of mesh generation. It is especially useful for simulating complex geometries, porous or inhomogeneous materials. The main idea for mesh generation in the FCM can be seen in Figure 1. The physical domain Ω with all curved boundaries, pores, and inclusions is embedded in the domain Ω_e which can be readily meshed into a Cartesian grid (*cells*) with quadrilaterals in 2D or hexahedrals in 3D. Cells completely outside of the physical domain are simply discarded. The boundary, pores and the different material properties are taken care of during the integration of the stiffness matrices of the cells. In this way, the effort for mesh generation is replaced with the numerical integration task, which can be performed in a fully automatic fashion. The quality of the finite cell approximation is controlled by both increasing the polynomial degree of the hierarchic shape functions and the accuracy of the integration procedure. A detailed description of the method can be found in [1-3].

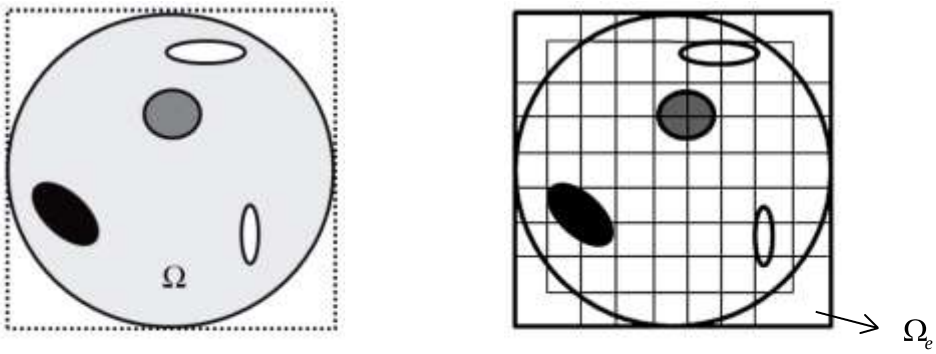


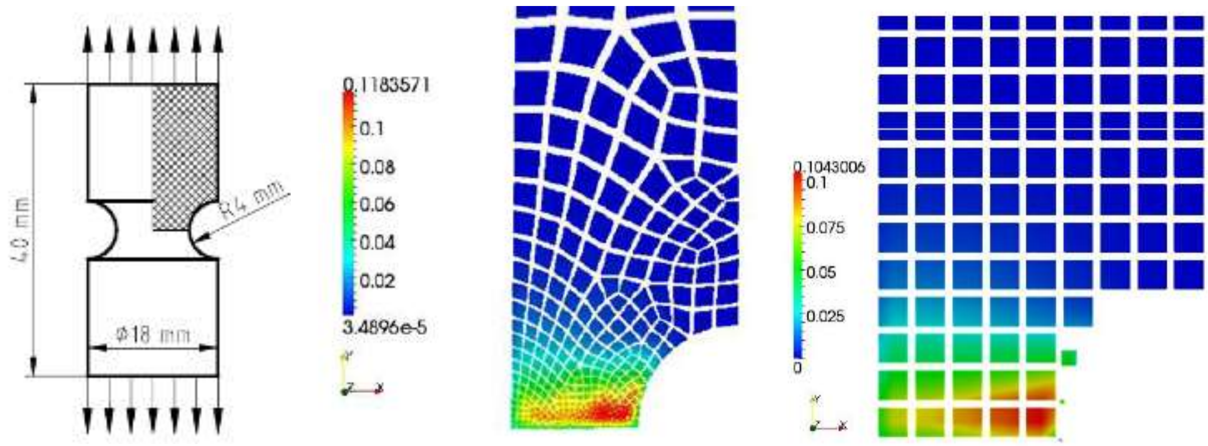
Figure 1: The physical domain Ω and the embedding domain Ω_e .

Continuum damage mechanics (CDM) has been extensively used in fracture analysis recently. The constitutive equations of the CDM can be divided into two main groups based on the continuum theory which has been employed: local and nonlocal continuum damage mechanics. Local CDM suffers from the mesh sensitivity problem; in nonlocal formulations this problem is solved by introducing an averaged state variable in the physical domain:

$$\Re(\phi) = \bar{\phi}(x) = \int_{\Omega} \beta(x,y)\phi(y)dy \tag{1}$$

In (1) $\Re$ is an averaging operator, ϕ is the averaged state variable and β is a weight function in the $x-y$ Cartesian coordinate system.

FCM is a good choice for damage analysis of structures with complex geometries or heterogeneous materials. Developing the finite cell method for a local damage theory is reported in [4] and its advantages and drawbacks are discussed. To overcome the mesh sensitivity and localization problems, a nonlocal integral formulation based on the average of the damage variable in the corresponding domain is used. The finite cell method is developed for this formulation to predict the crack initiation in ductile materials. The results are in good agreement with experiments and the literature. Despite the local damage constitutive law, the nonlocal formulation shows good convergence either by refining the mesh or by increasing the polynomial degree of shape functions. Figure 2 shows the geometry of a pre-notched bar as well as a comparison between damage parameter in FEM and FCM.



(a) (b) (c)

Figure 2: (a) Geometry of the notched bar, (b) FEM analysis of the damage and (c) FCM representation of the problem.

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