Weak Coupling Analysis for the Desiccation Cracking

Sayako Hirobe* and Kenji Oguni†

* Keio University Graduate School of Science and Technology
School of Science for Open and Environment System
Hiyoshi 3-14-1, Kohoku-ku, Yokohama 223-8522, Japan
e-mail: s.hirobe@keio.jp

†Keio University, Department of System Design Engineering
Hiyoshi 3-14-1, Kohoku-ku, Yokohama 223-8522, Japan
e-mail: oguni@sd.keio.ac.jp

ABSTRACT

The desiccation cracks are formed in the drying process of materials. These cracks tessellate the drying surface of the materials into polygonal cells with typical sizes. The previous experimental researches show that the size and the shape of the polygonal cells change systematically depending on the thickness of the specimen. This implies the existence of the common governing mechanism behind the desiccation cracking.

In the desiccation crack phenomenon, the inhomogeneous shrinkage due to the evaporation from the open-air surfaces and/or the external geometric constraint produces the excessive stress resulting in the fracture. Therefore, the desiccation crack phenomenon can be divided into three physical processes: desiccation, deformation, and fracture. The description of the desiccation process of the permeable materials is simplified to the diffusion equation in terms of the volumetric water content. On the other hand, the deformation of the materials corresponding to the change in the water distribution is expressed by the equation of the force equilibrium by assuming the materials as the isotropic linearly elastic body. The fracture due to the inhomogeneous shrinkage produces the strong discontinuity in the water content field and the deformation field. The coupling of these physical processes plays an important role in the pattern formation of the desiccation cracks.

In this research, we model the desiccation crack phenomenon as the coupling of desiccation, deformation, and fracture. Based on this coupling model, we perform the numerical analysis by using FEM and Particle Discretization Scheme Finite Element Method (PDS-FEM). PDS-FEM is a fracture analysis method which can treat deformation and fracture seamlessly. The FEM analysis (for the desiccation) and the analysis of PDS-FEM (for deformation and fracture) are weakly coupled.

Through the numerical analysis, we observe (i) the crack propagation process, (ii) the polygonal cells with typical sizes, and (iii) the change in the size and the shape of the cells with respect to the specimen thickness. The numerical analysis results show the satisfactory agreement with the results of the drying experiment with calcium carbonate slurry performed by the authors.

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