8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

Eulerian Finite Cover method for multi-scale analysis of large deformed composites

***Mitsuteru Asai [1], Kenjiro Terada [2] and Atsushi Maruyama[3]**

[1] Kyushu University
744 motooka, Nishi-ku,
Fukuoka, 819-0395
E-mail address:
asai@doc.kyushu-u.ac.jp

[2] Tohoku University
Aza-Aoba 6-6-06, Aramaki
Aoba-ku, Sendai, 980-8579
E-mail address:
tei@civil.tohoku.ac.jp

[3] Tohoku University
Aza-Aoba 6-6-06, Aramaki
Aoba-ku, Sendai, 980-8579

Key Words: *Meshless method, Homogenization method, Composite material*

ABSTRACT

We proposed an Eulerian type meshfree method, named by Eulerian Finite Cover Method (Eulerian-FCM), for multiscale analysis of large deformed composite materials. The Lagrangian FEM is generally used in order to analyze deformed solids. The mathematical description using mesh is suitable for the notation of kinematics. On the other hand, the meshes are distorted during the large deformation analysis, and it causes numerical divergence in the iterative procedure. To overcome this problem, particle type methods (mesh less method) have been developed for solid mechanics in the last decade. In the other hand, mesh-free methods, including the PU-FEM, GFEM and X-FEM, are developing by enhancing the definition of the mesh and approximation (or weight) functions. Many mesh-free type methods have been applied to the crack propagation problem without remeshing.

The FCM is also recognized as one of the generalized FEM based on the PU condition. This has been derived from the manifold method (MM), which is originally proposed by G.H Shi [1]. The key feature is the use of mathematical and physical meshes named by the cover. Authors have proposed the FCM for crack propagation problem at infinitesimal strain [2]. In this paper, we use the FCM as an Eulerian type solver for large-deformed composites. The point is the fixed mathematical girds, which define weight functions, can be utilized for large-deformed bodies without updating the grids. In other words, only the physical covers should be updated during the large-deformation analysis. The detail of the formulation with hyperelastic materials is found in [3]. Main problem remains the mapping of historical mechanical properties, for example the deformation gradient in the large deformation problem and the plastic strain (or plastic part of deformation gradient) in the elastic-plastic analysis. We first discuss accuracy of the mapping algorithms, and then we apply the Eulerian FCM to the multi-scale analysis based on the homogenization method.

The Multi-scale analysis provides a micro- and a macro-scopic problem. In this work, microscopic problems, in which unit-cell boundary should be satisfied periodicity, is analyzed by the Eulerian FCM. Multi-phase materials in the microscopic problem are described by the multi-layer covers as shown in Fig.1. The boundary on the different

layer is interacted by the penalty method in order to satisfy the material interface conditions.

Fig. 2 and Fig.3 show typical numerical examples in the microscopic problem. The stiffness of matrix is much smaller than that of inclusion. These constituents are modelled by Neo-Hookean model that is one of the hyperelastic constitutive models. Matrix deforms at large strain, but these behaviours are described by the Eulerian grid. The robustness for the large-deformation solver is checked by comparisons between the Eulerian FCM and conventional FEM.

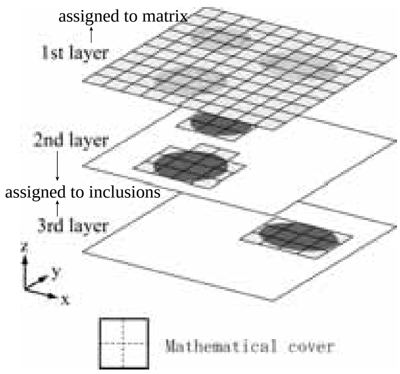

Fig.1 Multi-layer mathematical cover for description of composite material behaviors

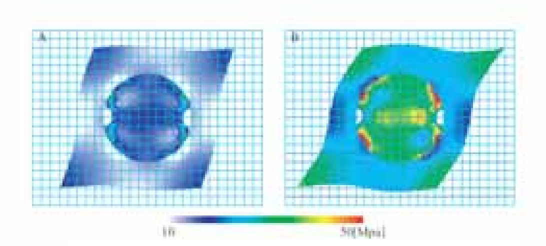

Fig.2 Shear deformation of a hyperelastic compsite

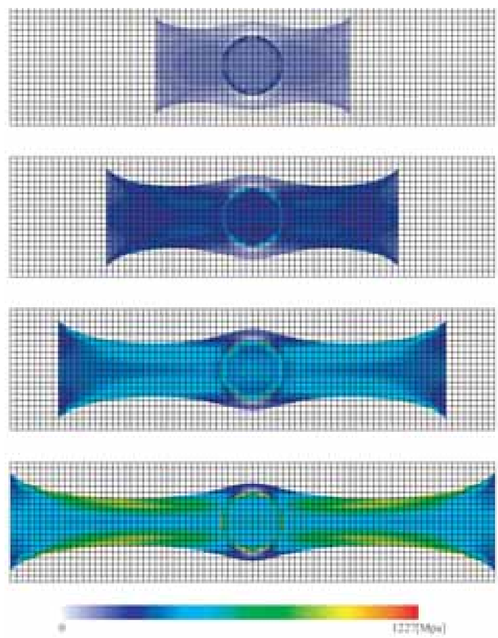

Fig.3 Uniform tension of a hyperelastic compsite

REFERENCES

[1] G.H. Shi, “Numerical Manifold Method”, *Proceeding of the 2nd International Congress on Analysis of Discontinuous Deformation.* pp.1–35, (1997).

[2] K. Terada, M. Asai and M. Yamagishi, “Finite cover method for linear and nonlinear analyses of heterogeneous solids”, *International Journal for Numerical Methods in Engineering.* Vol. **58**, pp.1321–1346, (2003).

[3] K. Terada, A. Maruyama and M. Kurumatani, “Eulerian finite cover method for quasi-static equilibrium problems of hyperelastic bodies”, *Communication in Numerical Methods in Engineering.* Vol. **23**, pp.1081–1094, (2007).