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Stochastic Analysis for Homogenization Problem Considering Microscopic Uncertainty using Kriging Approximation

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ABSTRACT

An inhomogeneous material such as a composite material has a complex microstructure, and each component material may have uncertainty in its geometry or a material property. A microscopic uncertainty may also arise in a manufacturing process of composites, and it will be difficult to be accurately controlled. Also, new materials such as nanocomposites or green composites will include a larger stochastic variation in a microstructure. Since this uncertainty will cause a stochastic variation of a homogenized property of the composites, a stochastic homogenization analysis will be needed for improvement of reliability of a composite structure.

For this purpose, several results of a multiscale stochastic analysis have been reported [1-3]. Especially, the perturbation-based homogenisation procedure will be available for estimating a stochastic characteristic such as the expectation or variance of a homogenized material property considering a microscopic uncertainty. However, the perturbation-based method will be difficult to be applied to a stochastic homogenization analysis considering geometrical uncertainty in case of using the homogenization method, since it requires an explicit form of a basic formulation. Also, the perturbation method should be applied to a problem with a relatively small variation.

In this paper, for this problem, a new stochastic homogenization analysis method is proposed. The method is based on a variable transformation of a stochastic density function and a function approximation technique. In our study, the Kriging method [4] is used for approximation.

The Kriging method will be applicable to approximation of an unknown function, and it is easy to compute a gradient or Hessian of an approximated surface [5]. In addition, a new formulation for estimating an integral of an estimated surface is also introduced.

In this presentation, a basic formulation and procedure for the proposed stochastic homogenization analysis are introduced. As a numerical example, a stochastic homogenization problem considering uncertainty of geometry or material property in a microstructure is solved using the proposed method.

Comparing the resuls of the proposed method with that of the Monte-Carlo simulation and the perturbation method-based homogenization analysis, validity and effectiveness

of the proposed method will be shown. With using the proposed method, a more accurate estimation of stochastic characteristics of a homogenized material property caused by uncertainty in a microstructure than the perturbation method and the stochastic homogenization problem will be analyzed at a lower computational cost than the Monte-Carlo simulation.

REFERENCES

[1] M. Kaminski and M. Kleiber "Perturbation based stochastic finite element method for homogenisation of two-phase elastic composites", *Comput. Struct.*, Vol. **78**, pp. 811–826, (2000).

[2] X. F. Xu and L. Graham-Brandy, "A Stochastic Computational Method for Evaluation of Global and Local Behavior of Random Elastic Media", *Comput. Meth. Appl. Mech. Engn.*, Vol. **194(** 42-44), (2005), pp.4362-4385.

[3] S. Sakata, F. Ashida, T. Kojima and M. Zako, "Three-dimensional stochastic analysis using a perturbation-based homogenization method for homogenized elastic property of inhomogeneous material considering microscopic uncertainty", *Int. J. Solid. Struct.*, Vol. **45 (**3-4), pp 894-907, (2007).

[4] H. Wackernagel, *Multivariate Geostatics*, Springer, (2003).

[5] S. Sakata, F. Ashida and M. Zako, "Structural Optimization Using Kriging Approximation", *Comput. Meth. Appl. Mech. Engn.*, Vol. **192 (7-8)**, pp. 923–939, (2003).