REPRESENTATION OF RANDOM COMPOSITE MATERIALS USING BASIS FUNCTIONS EXTRACTED FROM PRINCIPAL COMPONENT ANALYSIS

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This work is part of a larger project [1] which has as its goal to find the location of damage initiation within a random microstructure using image processing classification techniques rather then high fidelity finite element analysis. The approach is based on the decomposition of representative volumes of the material microstructure using a set of basis function derived from microstructures that have been classified as strong or weak. A classification tree derived using Bayesian heuristics is then used in a moving window framework to identify sites of likely damage initiation.

Here, attention is focused on the determination of the appropriate set of basis functions for microstructure representation, and an analysis of the quality of the approximate representation. Sample microstructures are initially represented as high-dimensional random vectors containing random variables associated with the material type of different locations within the representative volume. Classification of high-dimensional representations would be inefficient, so dimension reduction is done by determining a set of basis functions using principal component analysis on the random vector representations, and then selecting a subset of basis functions to define a reduced order space of microstructural descriptors. This is a complementary approach to other dimension reduction methods being used in microstructural representation [2].

In order to perform a principal component analysis and extract the appropriate basis functions a large number of samples of the cross section of a fiber reinforced composite are randomly generated. The samples are periodic and the inclusions are uniformly distributed within the matrix .The number of inclusions is also a random variable with poisson distribution so that the inclusions centers are a sample of a hard-core Poisson point field. Finite element analysis is used to determine the stress and strain fields in the sample microstructures under the conditions of uniaxial extension and periodic boundary condition. The samples with the maximum ratio of effective strain to failure strain occurring at the center of the sample are classified as critical, and those with this maximum occurring at the corner of the sample are classified as non-critical. Using the concept of periodicity of the microstructure the weak and strong type samples are generated just by shifting the location of window such that the maximum strain ratio occurs at the center and the corner of the sample respectively. Then principal component analysis is performed on the critical and non-critical samples, as well as the original, unclassified samples.

Any new microstructure, which is not contained in the dataset used for principal component analysis, can be represented by being projected on the newly determined basis functions. In order to find an appropriate linear combination of the basis functions used in this projection several parameter studies are done so as to find the number of samples needed in principal component analysis as well as the number of basis functions needed to represent new microstructure with appropriate accuracy. This parameter study is done for the principal component analysis of weak and strong samples as well as that of the original one. In addition, some preliminary results are presented which show how this microstructure representation can be used in mechanics based classification, and may provide an efficient route to microstructural design.

References

[1] H. Liu, S.R. Arwade and T. Igusa,“ Random composites characterization and damage estimation using a classifier model,”*16th Engineering Mechanics Conference. Seattle, Washington,*

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