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Effect of neighbor heterogeneity on local stresses in two phase stochastic composite

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ABSTRACT

The aim of this study is to evaluate the effect of stochastic heterogeneity on local stresses. In particular, we are interested in the neighbor heterogeneity which causes extreme stresses. This topic is fundamental for the analysis of a wide variety and scales of heterogeneous materials: fiber and whisker composites, asphalt, sintered materials, syntactic foams, concrete, geological materials, biological materials such as bones and nanostructures. The importance of the study stems from the fact that invariants of local stresses (maximum shear etc) or strains (maximum normal strains) are common basis for design against failure. The strength and reliability of many of these materials is strongly dependent on localized stress concentrations in small regions having partially ordered (random) micro neighborhood. Evaluate the effect of stochastic heterogeneity on local stresses can help Designing advanced materials with improved morphologies (by Avoiding "dangerous" neighbor morphologies), and consequently improved performance of the new materials.

Two major objectives are pursued, which compliment each other:

a.) Given a random morphology, find the local neighborhoods which are more susceptible to failure and their probability of occurrence

b.) Given a macro geometry and external loading, find the characteristics of morphologies with better resistance (strength).

The milestones for achieving these two goals are:

a.) Find approximated for the stress based on Functional Perturbation Method (FPM), and MCS (Monte Carlo Simulation)

b.) Using (a), find analytically, the amount and extent (in statistical terms) of high stress low strength neighborhoods

c.) Test the accuracy and predictive capabilities of (a, b) by comparing with Finite Element simulations (regular and stochastic). Find analytically, and validate numerically, the size of neighborhood in which the morphology may affect the local extreme stress

It is found that:

a.) The maximum local stresses occur when volume fracture of the stiffer material is around ~30%

b.) Stress Prediction based on a local radius of ~3 "grains" is reasonably accurate

c.) Second order perturbation yields a good approximation and therefore the FPM is a candidate for future analytical predictions

d.) Fiber like morphologies parallel to the loading direction exhibits the extreme stresses (both maximum and minimum)

e.) Local stress distribution is not Gaussian and has two distinguishable sub-shapes, one for each material.

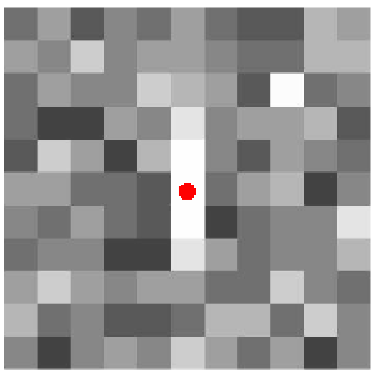

Figure: Average moduli map of 10 morphologies with extreme Von Mises stress at the test point (red circle). Whiter colors represent higher modulus. Higher local stresses at x show a strip like configuration of stiff material B .

Morphologies which exhibit extreme relative stresses (normalized to the yield stress for each material) are currently studied. So far the study shows that the relative stresses have different characteristics in concern with morphology and extreme stress.

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