Modeling Crack Propagation in Heterogeneous Materials Using a Computational Homogenization Method

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The modeling of crack propagation in heterogeneous materials using a computational homogenization method is presented.
In the computational homogenization method, the macroscopic properties of each material point are obtained by solving a boundary value problem for a representative volume element (RVE). When localization occurs in the material, the assumption of homogeneity of stress and strain over the local-scale breaks down and one cannot use standard homogenization scheme.
An objective continuous-discontinuous homogenization scheme [1] is developed based on a failure zone averaging method [2] which can be used to homogenize the traction-separation law for a macrocrack from the heterogeneous local-scale. The macrocrack is modeled as a strong discontinuity using XFEM and a gradient-enhanced damage model is used to model diffuse damage at the local-scale.
The continuous-discontinuous scheme is extended to dynamic problems in which the macroscopic wave length is significantly larger than the local-scale length. Under this condition, the local-scale problem can be solved as a quasi-static problem.
In the continuous-discontinuous scheme, the loss of hyperbolicity criterion [3] is employed for crack initiation and propagation. Based on this criterion localization initiates when the momentum equation loses hyperbolicity and the vector that minimizes the hyperbolicity indicator is normal to the direction of the crack (localization). In the multi-scale analysis, this criterion can be used to detect localization in the RVE. At each time step, the acoustic tensor can be calculated from the homogenized tangent modulus. Initiation and direction of the crack can then be determined using the hyperbolicity criterion. The advantage of this criterion is that both initiation and direction of the crack can be obtained from a local-scale analysis.
Furthermore, rate effects are taken into account in the model by relating the material properties of the RVE to the rate of the macroscopic crack opening.
Using the present model, numerical examples are presented for crack propagation in heterogeneous media and the influence of the loading rate on cracking is studied.

References

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