Abstract

In this thesis, the modeling of dynamic damage and failure of quasi-materials is addressed using a two-scale approach based on the asymptotic homogenization method. Dynamic damage laws are obtained and numerical simulations of the associated behavior are performed for loadings corresponding to the classical three modes of Fracture Mechanics. The first dynamic model of damage is proposed for the anti-plane shear loading case (Mode III). The damage evolution law is deduced from the Griffith's energy criterion governing the dynamic propagation of microcracks, by using the homogenization method based on asymptotic expansions. A study of the local macroscopic response predicted by the new model is conducted to highlight the influence of parameters, like the size of the microstructure and the loading rate, on the evolution of damage. Results of macroscopic simulations of dynamic failure and the associated branching instabilities are presented and compared with those reported by experimental observations. The model is implemented in a FiniteElements/Finite-Differences code using the Matlab software environment. Numerical simulations of rapid failure in opening mode (Mode I) are using a dynamic damage law are presented subsequently. The model is deduced from a microscopic Griffith type criterion describing the dynamic mode I propagation of microcracks, using the asymptotic homogenization approach. The resulting damage law is sensitive to the rate of loading that determines the macroscopic failure mode. Numerical simulations are performed in order to identify the model predictions and the obtained numerical results are compared with the experimental ones. Different tests, like the compact tension and L-shape specimen tests for concrete, the compact compression test for the PMMA brittle polymer and the Kalthoff impact test for limestone rocks, are considered in the numerical simulations. These simulations show that the loading rate essentially determines the macroscopic crack trajectory and the associated branching patterns, in agreement with the experimental results. The law has been implemented in a finite element code Abaqus/Explicit via a VUMAT subroutine. A third model of damage is obtained for the in-plane shear mode (Mode II) through a similar double-scale approach by considering unilateral contact with friction conditions on the microcracks lips. A local study concerning the effects of normal compression and of the friction coefficient is carried out. The influence of the size of the microstructure and the rate of loading on damage evolution is analyzed at the local level. These studies are completed by structural failure simulations of PMMA specimens using the Abaqus/Explicit finite element software.

Keywords: Quasi-brittle materials, dynamic damage law, microcracks, two-scale modeling, numerical simulations.