A One-Dimensional Micromechanical Model of Elastic-Microplastic Damage Evolution

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With 9 Figures

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Summary

A one-dimensional micromechanically based model of elastic-microplastic damage evolution is presented. The deterioration of the material is represented by Dugdale microcracks. Postulating a physically plausible crack growth law a consequent homogenisation predicts the macroscopic hardening and softening behavior during a loading process as well as the corresponding continuous damage evolution and typical characteristics during a final unloading process.

1. Introduction

Non-linearities in the constitutive equations very often result from a process of increasing microstructural deterioration (for example initiation and growth of microcracks and microvoids). In order to describe the accumulative material degradation by means of continuous field variables Continuum Damage Mechanics [1]—[3] has come up and meanwhile has reached a fairly advanced stage of development.

Ordinarily two different ways are pursued. Firstly there are predominantly phenomenological damage models, usually embedded in a rational thermodynamical framework, containing free parameters which have to be determined by fitting experimental data [2], [4]. Secondly there is the micromechanically oriented way. Here on the one hand the microscopic behavior of idealized elementary defects (voids, cracks) is considered [5], on the other hand the continuum mechanical “overall effect” of those defects is investigated on this basis [6]—[8]. As materials essentially differ in their micromechanical behavior they naturally can not be described altogether equally well by one single model.
In this paper a simple micromechanically based continuum damage model is proposed. It is to apply for brittle-ductile materials that are neither too brittle nor too ductile. Basic assumption is that the macroscopic material damage can be described by the behavior of a representative unit cell. In that cell elastic-microplastic damage is simulated by a Dugdale crack for which a plausible crack growth law is postulated during an external loading process. During unloading rigid plastic zones are prescribed.

The model is to be kept simple by confinement to the 2-dimensional Dugdale crack problem, admitting only uniaxial tensile loading and neglecting any crack interaction. In the sense of linear elasticity strains are assumed to be microscopically and macroscopically sufficiently small. It turns out that the model in principle can describe all the experimentally observable phenomena as hardening, softening, damage-induced weakening, irreversible strains and porosity. The Dugdale crack consideration of course is a model idealization only and is not to deny the various possibly different natures of actually involved micromechanisms.

2. Model Description, Loading Behavior

It is assumed that the uniaxial overall material behavior of an extended plate can be described by the properties of a representative unit cell of volume $V_0 = e^2$. In this cell elastic-microplastic damage is modeled by a mode I loaded Dugdale crack (length $2a$, yield strip length $b - a$, see Fig. 1). The crack itself is to represent an elementary crack-like defect. The yield strips are to globally represent dissipative inelastic effects accompanying defect growth.

In this approach no interaction between any cracks (respectively unit cells) is considered. That means the Dugdale crack is to behave as one in an infinitely extended plate. For such a configuration the opening displacements $v^+(x)$ of the

![Fig. 1. Dugdale microcrack in unit cell](image-url)