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A DISSIPATION-BASED ARC-LENGTH METHOD FOR ROBUST SIMULATION OF FAILURE

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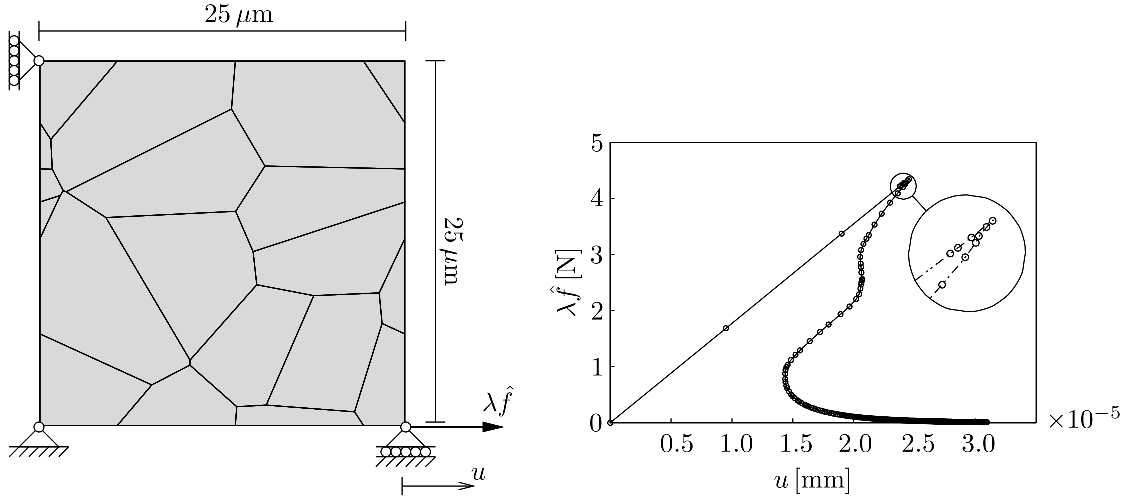
ABSTRACT

Computations for quasi-static nonlinear solid mechanics problems are often carried out for the purpose of determining important characteristics such as the maximum load or the residual strength at a given strain level. Determination of such properties often requires tracing of the whole equilibrium path. The availability of a robust method for stepwise determination of the required points of the equilibrium path is therefore indispensable.

Several approaches have been proposed in the past. The pioneering work of Riks [1] is worthy of mention, together with the alternative formulations by Ramm [2] and Crisfield [3]. A comprehensive review of the available techniques is provided by Geers [4]. The traditional approach consists of parametrising the equilibrium path with its own arc parameter, which motivates the generic ”arc-length” denomination for this kind of methods. The arc parameter works properly for problems exhibiting geometrical nonlinearities but often fails when material instabilities are involved that would lead to localised failure process zones. A remedy for this is to consider only the degrees-of-freedom involved in the failure process to be coupled to the path parameter [5]. While such an approach is robust in general, it is not applicable when the location or behaviour of the failure process zone is not a priori predictable. This is the case when Monte-Carlo simulations of failure of heterogeneous materials are carried out or when crack propagation or interfacial delamination is the relevant dissipative phenomenon. Remedies for this problem, based on coupling the path parameter to smartly selected internal variables, have been proposed in [4]

A path following constraint based on the energy release rate in the case of a geometrically linear continuum damage model was introduced in [6]. This method has the advantage that the dissipated energy is a global quantity and therefore no a priori selection of degrees-of-freedom is required. Moreover, as such a constraint is directly related to the failure process itself, a stable convergence behaviour is observed even for far advanced stages of the equilibrium path.

In this contribution the path following constraint as proposed in [6] is extended and applied to the case of geometrically linear plasticity computations and geometrically nonlinear damage computations. In



addition, the method is applied in the context of the partition of unity method. From a computational point of view, all constraints can be used without much additional computational effort compared to classical arc-length constraints. Furthermore, the simplicity of the constraints makes them attractive to implement.

The proposed arc-length constraints will be demonstrated for the three cases considered. The case of the geometrically linear damage constraint is demonstrated using a discrete cohesive zone computation based on the partition of unity method. The constraint for geometrically linear plasticity is demonstrated using a numerical example of a polycrystal with plastic interfaces. Finally, the geometrically nonlinear damage constraint is used to carry out a buckling delamination computation. All examples show that the proposed constraints can be used for robust tracing of the equilibrium path.

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