Mesh Size Independence in Microplane Models

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ABSTRACT

The nonlocal generalization of damage type constitutive models that leads to finite element solutions independent of element size can easily be achieved by a nonlocal averaging of the fracturing part of the inelastic strains over a material volume of suitable size [1]. In the nonlocal approach, however, a number of difficult problems arise. One problem is the treatment of the boundary conditions. The protruding part of the averaging volume beyond the boundary may simply be discarded provided that the weight function is rescaled over the part that remains in the body. Alternatively, the contribution of the protruding part may be represented by a Dirac delta function. Yet another alternative is the use of a "boundary layer" that exhibit mesh-size dependent local material behaviour [2]. Furthermore, a variety of weighting functions can be used in the nonlocal integral. Each of these variations result in different material responses.

Another problem encountered in the application of nonlocal approach to the Microplane type models in which the material behaviour is prescribed on planes of various orientations in terms of strain-dependent yield functions is the difficulty of isolating a monotonously increasing internal variable characterizing the damage in the model. In such formulations isolating the fracturing part of the strain is not possible under arbitrary loading. One proposed solution to this problem is the so-called "over-nonlocal" approach in which the averaged inelastic variable of choice is replaced by the over-nonlocal variable obtained by multiplying the averaged inelastic variable by a factor of n and adding (1-n) times its local counterpart. Although the factor $n>1$ in principle is considered to be a constant, it must depend on the maximum inelastic principal strain in the case of nonlocal Microplane models [3], which further complicates this approach.

In this study, we propose a simple alternative to the nonlocal approach in the form of crack band approach with automatic recalibration of the material parameters related to the softening behaviour. To this end, we determine the variation of the parameters c_2, c_3, c_4, c_7 and c_8 of the Model M7 [4], which are the only parameters that pertain to the softening behaviour, as functions of the size of finite elements of aspect ratio of approximately 1. We determine the variation of these parameters with element size by simultaneously fitting both tensile and compressive load-deformation curves through 3D finite element analyses of test specimens discretized with a uniform mesh of finite elements of a given size and an aspect ratio of approximately 1. The resulting functional relations allow the model to be automatically recalibrated for a wide range of element sizes without suffering the aforementioned problems exhibited by the nonlocal formulations and still achieving finite element solutions independent of element size. Furthermore, the numerical application of this approach remains as fast as element size dependent crack band approach while nonlocal formulations drastically increase the computational cost of finite element analyses.

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