

Scaling Laws for Damage Evolution in Disordered Materials: Numerical Aspects¹

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Abstract

Scaling laws derived from mesoscopic discrete lattice models are typically used for coupling the mesoscopic damage evolution with the continuum damage response and in determining the size effects on the constitutive response of materials. This study develops the scaling laws for damage evolution based on the Renormalization Group (RG) methodology. The developed scaling laws imply the existence of a finite critical fracture threshold, below which macroscopic fracture of an infinite system does not occur. This result is in contrast with earlier results based on power law curve fit expressions, wherein the critical threshold approaches zero in the limit of an infinite system. However, the existence of a finite critical fracture threshold may be associated with a critical crack size, below which macroscopic fracture of a specimen does not occur.

Numerical simulations based on two-dimensional triangular and diamond lattice networks substantiate the proposed scaling laws and are used to estimate the critical thresholds and the scaling exponents. The computational bottleneck involved in modeling the fracture simulations using large discrete lattice networks is that a new set of governing linear systems of equations need to be solved everytime a lattice bond is broken. This study presents an algorithm based on rank-one update of the matrix inverse for modeling the relaxation processes in disordered systems. Using the present algorithm, the computational complexity of solving a new set of linear system of equations after breaking a bond reduces to a simple *backsolve* (forward elimination and backward substitution) using the already LU factored matrix. This algorithm using the direct sparse solver is faster than the fourier accelerated iterative solvers such as the preconditioned conjugate gradient solver, and eliminates the *critical slowing down* associated with the iterative solvers that is especially severe close to the percolation critical points. Numerical results using random resistor networks for modeling the fracture and damage evolution in disordered materials substantiate that simulations using the present algorithm are much faster compared to the competent fourier accelerated preconditioned conjugate gradient solvers.

In fracture simulations using the discrete lattice networks, an ensemble averaging of numerical results is necessary to obtain a realistic representation of the lattice system response. In this regard, and in the case of very large lattice systems, the main advantage of the algorithm presented in this paper is that it provides an attractive technique wherein the matrix of linear equations can be LU factored on multiple processors using a *parallel* implementation at the beginning of the analysis, and then the factored matrix can be distributed to each of the processors to continue with independent fracture simulations as they only involve backsolve operations.

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