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An Enriched Quasi-Continuum Approach to Crack Propagation in Discrete Lattices

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Lattices of trusses or beams have been successfully employed for decades to model the effect of microstructure on the macroscopic response of discrete materials, such as foams or textiles, as well as of heterogeneous materials such as concrete. However, for real engineering scale applications such models suffer from a prohibitive computational cost due to the fact that the large separation between the scale of the microstructure and that of the macroscopic engineering structure necessitates an enormous number of elements (trusses or beams). In damage and fracture problems, where the mechanics of the problem is governed by the microstructural evolution of a limited part of the structure, fully resolving the microstructure may also be unnecessary.

In the present study we develop a multiscale methodology for precisely this type of problems. The method is based on the Quasi-Continuum (QC) method, a concurrent multiscale method originally designed by Tadmor *et al.* [1] for conservative atomistic systems. The method has been extended more recently to dissipative interactions, first on a heuristic basis in [2] and later more systematically on the basis of the minimization of incremental energy [3, 4].

Here we develop a strategy to adaptively refine the QC discretization to full resolution (i.e. to the lattice spacing) in those regions where the damage evolves, whereas full benefit is taken of the QC coarsening where the damage is inactive. In particular, an X-FEM enrichment is employed in the wake of the crack tip in order to allow coarsening in this region as well. This strategy ensures that the 'true' physics of the microstructural model are captured in the process zone, while nevertheless managing the computational tractability of the problem.

The performance of the method is demonstrated by a number of example problems. Figure 1 shows a preliminary result of a simulation of crack initiation and propagation in a Single Edge Notched Beam loaded in shear. The underlying lattice has an X-braced unit cell consisting of damageable trusses. The damage evolution results in the initiation of a crack at the notch tip. The crack then propagates in along the curved path which is so characteristic for this problem. At each stage of the simulation, the process zone is fully resolved. Away from the crack tip, however, including in the wake of the crack tip, the QC discretization is substantially coarser than the lattice spacing.

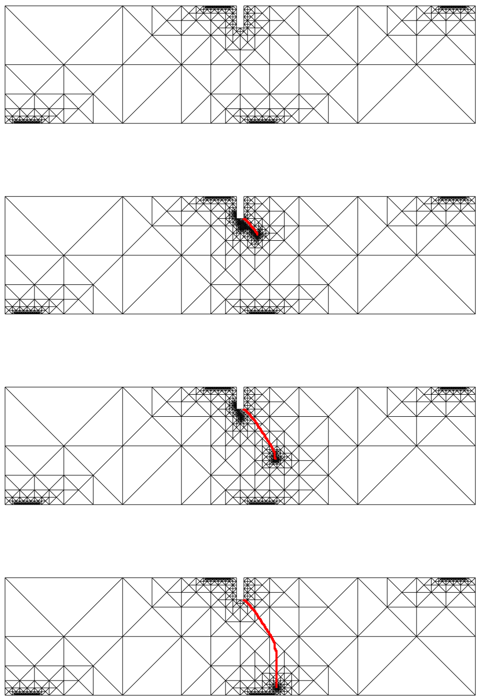

Figure 1: Application of the enriched QC methodology to a Single Edge Notched Beam under shear. Shown is the evolution of the QC triangulation as the crack (in red) grows. The underlying X-braced lattice is always fully resolved in the process zone. Note the coarsening of the discretization in the wake of the crack tip, by virtue of the enrichment.

References

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