State-dependent sweeping process approach to Lattice Spring Models with softening plasticity: modeling and existence of solutions

Ivan Gudoshnikov

January 5, 2023

Gurson model of damage and softening plasticity lead to ill-posed mathematical problems due to the loss of monotonicity. Multiple co-existing solutions are possible when softening elements are coupled together, and solutions cannot be continued beyond the point of complete failure of a material.

We present a state-dependent sweeping process which solves the evolution of elasto-plastic Lattice Spring Models with arbitrary placement of softening, hardening and perfectly plastic springs. We prove the existence of solution to the associated time-stepping problem (implicit catch-up algorithm), and the estimates we obtain imply the existence of a solution to the time-continuous problem.

Using numerical simulations of regular grid lattices with softening we demonstrate the development of non-symmetric shear bands and stress concentrations. At the same time, in toy examples it is easy to analytically derive multiple co-existing solutions. These solutions correspond to fixed points in the implicit catch-up algorithm and we observe a discontinuous bifurcation with the exchange of stability of those fixed points.