Topology optimization for effective energy dissipation in elastoplastic systems

Praveen Nakshatrala[1], Daniel Tortorelli[2]

[1] Graduate Research Assistant and Presenting Author, Mechanical Engineering, University of Illinois, Urbana, IL, USA e-mail: pnaksha2@illinois.edu
[2] Professor, Mechanical Engineering, University of Illinois

A topology optimization framework for effective energy propagation in material systems subjected to impact loading is proposed. The goal of the optimization is to distribute the constituent phases such that we mitigate the impact loads. To generate a problem amenable to optimization, we use the SIMP method [1] to convexify the design space by replacing the binary valued design parameters with a smoothly varying design volume fraction function. Length scale restrictions on the features appearing in the design are imposed via a consistent filtering technique.

We consider small deformation von Mises plasticity of isotropic materials with linear work hardening and use a locally defined flow stress as the state variable. A multilevel nested Newton i.e., a consistent tangent approach is used to integrate the constitutive equation. Through the use of topology optimization, we distribute two different materials within a design domain such that we dissipate maximum amount of energy in an impact problem. We use a gradient based optimization algorithm to update the design and this requires the derivatives of the cost function with respect to design parameters. An analytical adjoint sensitivity analysis cf. [2] is used to compute these derivatives. An important thing to note is that for path dependent problems, the sensitivities are also path dependent. In this adjoint terminal value problem, we reuse the consistent tangent operators stored from the primal initial value problem. An optimality criteria based algorithm is used to update the design.

In a fully discretized transient setting, at each time step, thousands of local state variable evolution equations are solved for one global momentum balance solution, making this a computationally expensive problem and hence we use the single program multiple data parallel programming paradigm of MPI to make the problem computationally tractable. The optimization framework is applied to 3D design problems and the results for elastoplastic materials are compared to the linear elastic materials.

References

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