

DIRECT SENSITIVITY ANALYSIS IN A MIXED LAGRANGIAN TIME STEPPING FRAMEWORK

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Abstract

The optimization of transient structural response is computationally demanding, as it requires time integration schemes that remain stable and efficient over highly nonlinear, time-dependent design spaces. The Mixed Lagrangian Formalism (MLF) addresses this challenge by casting the state update at each time step as a constrained optimization problem. This perspective has demonstrated excellent robustness and numerical stability across a broad range of nonlinear transient applications in structural dynamics and coupled multi-physics settings, particularly when strong material and geometric nonlinearities are present. However, the optimization-based structure of MLF complicates the computation of design sensitivities, which are essential for gradient-based response optimization.

In this presentation, we discuss a sensitivity analysis strategy for MLF that enables the efficient evaluation of first-order derivatives of the transient response with respect to design variables. The approach relies on the direct differentiation of the Karush--Kuhn--Tucker (KKT) optimality conditions that characterize the MLF sub-problems at each time step. By implicitly differentiating the equilibrium conditions, the method yields consistent response sensitivities while preserving the robustness of the underlying time-stepping scheme. The resulting framework supports gradient-based optimization of complex transient problems without introducing additional convergence difficulties in the forward time-history analysis. The methodology is demonstrated on a dynamic response optimization problem involving a structural system with tension-only elasto-plastic components and supplemental viscous damping devices.