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An explicit time integration approach for micromorphic damage formulations: theory and application

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Abstract

Explicit finite element solvers are widely employed to simulate complex industrial processes, particularly those characterised by high strain rates, complex contact interactions and rapid failure. They are indispensable for manufacturing simulations, including metal forming and impact loading. A key challenge lies in achieving mesh-independent solutions while accurately capturing the onset and evolution of damage localisation. Regularisation strategies are therefore required, with gradient-enhanced formulations representing a well-established approach. However, classic micromorphic formulations of gradient-enhanced damage models, as presented in [1], lead to elliptic partial differential equations and are therefore inherently incompatible with explicit solvers. To overcome this limitation, it was propsed in [2] to reformulate the field equations in a hyperbolic form, enabling their integration within explicit solution frameworks. Building on these developments, the present work explores dynamic micromorphic formulations tailored for explicit finite element analysis [3]. Dimensional and wave-propagation analyses are employed to study scaling characteristics and regularisation effects, and the resulting formulation is embedded into an explicit solver. The approach is subsequently validated on representative boundary value problems and its usefulness for metal-forming applications is shown.

Keywords:
Gradient-enhanced damage Micromorphic approach Dynamic formulation Explicit time integration Finite deformations Stability analysis