Fracture in viscoelasticity: Comparison of a phase-field and a lip-field approach

R. Gopalsamy[1]*, N. Chevaugeon[2], O. Chupin[1], F. Hammoum[3]

[1] Univ Gustave Eiffel, MAST-LAMES, F-44344 Bouguenais, France, rajasekar.gopalsamy@univ-eiffel.fr
[2] Ecole Centrale de Nantes, GeM Institute, UMR CNRS 6183,1 rue de la Noe, 44321 Nantes, France
[3] Univ Gustave Eiffel, MAST-MIT, F-44344 Bouguenais, France

The present work provides a comparison of one particular phase-field damage model and a lip-field damage model for viscoelastic fracture.

Fracture in viscoelasticity is a complex phenomenon due to a) its highly rate-sensitive behavior b) a significant amount of viscous dissipation happening in the bulk of the material around the crack tip c) added fracture toughness due to inertial effects for rapid crack growth. In this context, we are interested in the quasi-static response of a viscoelastic material subjected to damage. An incremental variational formalism has been proposed which allows embedding the local constitutive equations into a global incremental potential. The local constitutive equations to describe the viscoelastic behavior are represented using the Generalized Kelvin Voigt (GKV) model. The minimization of the global incremental potential with respect to the state variables then gives the solution to the mechanical problem. The definition of this incremental potential is such that only free energy contributes to damage growth.

The potentials considered for both phase-field [1], [2] and lip-field [3], [4] models are quite similar locally. Damage models in the local sense are well known to introduce spurious mesh-dependent results due to the loss of ellipticity of the mathematical problem. Introducing length scales into the model is the common way to circumvent this issue. The length scale in the phase-field model is introduced by the addition of a gradient term in the potential. In contrast, the lip-field preserves the potential in local form and the introduction of length scale is through the addition of a new space called Lipschitz space and constraining the lip-damage field to lie in this space.

The potentials considered for phase-field and lip-field models are convex with respect to each state variable separately. Moreover, the admissible spaces for the state variables are also convex. Hence an alternating minimization is used to solve for state variables at each time step until convergence. In contrast to phase-field, the minimization to find the lip-damage field is greatly simplified by the use of local/non-local minimization split [4]. This allows performing the expensive non-local minimization only in the region where the damage gradient is higher than the admissible value.

The length scales of both models are selected to have similar damage profiles. The model parameters are also calibrated to obtain the same surface fracture energy. Numerical results are then provided for the bi-dimensional tests. Both models are able to capture the rate-dependent effects typically observed in viscoelastic fracture. Moreover, qualitatively similar results are observed for both models. However, the phase field model is found to be more dissipative in nature.

References

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