Development of a viscoelastic damage model within the Thick Level Set framework

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ABSTRACT

This research deals with damage and fracture growth in viscoelastic solids. It aims to extend the Thick Level Set (TLS) (Moës et al, 2011) approach to viscoelasticity (VE); it is a non-local damage model embedding displacement discontinuity. The expected application is the modeling of cracking process in bituminous materials which represents a main mode of asphalt pavement distress. In particular, one seeks for a model that well reproduces the effects of temperature and loading speed, especially the transition between the fragile and ductile regimes usually observed in asphalt concrete specimens tested in the laboratory.

The TLS approach first requires the choice of a local VE damage model, preferably based on a finite set of internal variables.
The spectral decomposition of the Huet creep function (temperature dependent) considered here because well adapted to the modeling of asphalt concrete materials without damage, allows us to meet this condition. Indeed the search for damage models can then be based on simple rheological VE elements only. The Poynting-Thomson model combined with the concept of effective stress is selected as a first example. The local damage evolution is chosen as being independent of the physical time.
The non-local TLS formulation at the structural level is obtained by integrating the local damage evolution law over the thickness of the damaged zone.

This theoretical model is first applied to a semi-analytical problem dealing with damage growth in a viscoelastic bar (1D) subjected to traction. The problem is reformulated in terms of rate evolution in order to discuss the existence and stability of the solution as a function of the boundary conditions. The rate equations are then integrated numerically with respect to space and time for the whole assessment of the bar response which can be used as a reference solution.

The proposed model is then implemented in the TLS code developed at ECN. The finite element formulation is solved incrementally using an explicit prediction/correction. The implementation is validated against the aforementioned reference solution based on a 2D mesh of the bar. Finally, 2D-simulations of fracture tests carried out on asphalt materials, as the three point bending test on notched beam, are performed for different temperatures and loading speeds focusing on the analysis of the fragile/ductile transition.

Keywords: viscoelasticity, damage, fracture, TLS, asphalt materials

N. Moës, C. Stolz, P.E. Bernard, N. Chevaugeon, “A level set based model for damage growth: the thick level set approach”, *Int. J. Numer. Methods Engrg.* 86 (2011) 358– 380.