Fractional viscoelastic cohesive zone model with long-range interaction

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Keywords: Viscoelastic interface, nonlocal interface, damage model.

This paper is devoted to model the time-dependent crack propagation along a nonlocal viscoelastic interface. We consider this kind of problem where two main aspects of the mechanical behavior influence the crack propagation, namely, the long-range interaction and the rheological phenomena.

In detail, we study a double cantilever beam (DCB) with a viscoelastic nonlocal interface, as depicted in Figure 1. The nonlinear mechanical behavior of the interface is modeled with the aid of the cohesive zone models (CZMs). This kind of model has been used to describe the failure and the debonding phenomena of materials and interfaces [1, 2]. In this regards, in a recent work a CZM has been enriched introducing a displacement-based non-local elastic interaction in the interfacial constitutive law [3]. In this way, the debonding process is described taking into account the non-linear elastic local force and the long-range interactions depending on the relative displacements [4, 5]. In order to model the nonlocal effects, elastic interaction forces depending on the relative displacements and distance-decaying functions ruling the amount of interactions are introduced in the constitutive equation of the interface. However, in such paper the time-dependent effect on the mechanical behavior of the interface during the crack propagation is not considered. The present work aims to improve the nonlocal CZM by taking into account the time-dependent effects related to viscoelastic nature of the interface.

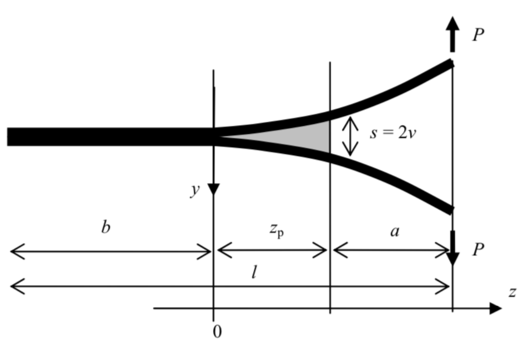

Figure 1: Double cantilever beam with viscoelastic interface

The introduction of time-dependent effects within analytical formulations has been investigated by several authors. Some interesting results have been provided in [6], where the rheological behavior is modeled with the aid of fractional-order operators in the stress-strain relation of the viscoelastic interface. By taking into account the time-dependent behavior and the long-range interaction by means of a nonlocal formulation, an integro-differential equation rules the DCB problem in Figure 1. That is,

$$EI\frac{\partial^4 s(z,t)}{\partial^4 z} + 2B\sigma(s,t) + k_{nl}B^2 \int_{-b}^{z_p} g(\xi,z)\Delta s(\xi,t)d\xi = 0 \tag{1}$$

where E is the Young modulus, I is the inertia moment of cross-section, B is the thickness, $s(t)$ is the relative separation between the two elastic beams, $\sigma(s,t)$ represents the stress-separation relation depending on a specific cohesive law, and the convolution integral models the nonlocal effects.

The analytical solution of Eq. (1) is not known in closed form. For this reason the numerical solution is achieved by a finite difference approximation and iterative incremental procedure to take into account the time-dependent nonlinear law in the cohesive zone model.

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