On the relations between fracture mechanics and damage mechanics of rate-dependent interfaces

O. Allix*, **and M. Jirásek**†

* LMT, ENS Paris-Saclay/CNRS/Université Paris-Saclay,
61 avenue du Président Wilson, F-94235 Cachan Cedex, France
e-mail: olivier.allix@ens-paris-saclay.fr

† Czech Technical University, Faculty of Civil Engineering, Department of Mechanics,
Thákurova 7, 16629 Prague 6, Czech Republic
e-mail: Milan.Jirasek@fsv.cvut.cz

ABSTRACT

The use of rate-independent cohesive models may lead to crack speeds much higher than those measured for real materials (see, e.g., [1]). An explanation is that when the crack speed increases, secondary microcracks develop; they diminish the energy available as a driving force of the main crack, and for the same main crack modify the macroscopic critical energy release rate [3]. This phenomenon was studied in [4] where a a rate-dependent cohesive crack model was proposed. In this context, the purpose of the present contribution is to analyse the fundamental properties of a rate-dependent cohesive model. We consider here the simplest case of a dynamic mode-II delamination, for which an important reduction of the crack speed has been observed [2]. The idealised problem of a crack along the interface between a semi-infinite elastic layer and a rigid substrate is studied. Solutions corresponding to the propagation of the crack tip at a constant velocity are constructed using a semi-analytic shooting method [5] for any set of parameters and crack speeds. An energetic analysis of the problem is presented, and the relation between model parameters, crack velocities and dissipated energy is then analysed.

For very low crack speeds, a linear increase of the applied force or the applied velocity with increasing crack speed indicates the presence of rate effects. It turns out that, even for a self-similar process, the rate effects are governed by the process zone. Since the distribution of damage along this zone depends on the structural configuration, rate effects cannot be seen as intrinsic to the interface. For a rate-dependent damage model, it is impossible to determine a unique dependence of the dissipated energy per unit area on the crack rate. Another conclusion is that even if the rate-dependent extension of the damage model is based on bounded damage rate, no additional restriction on the crack speed is induced and the theoretical limit is still given by the speed of elastic waves. Still, from the practical point of view, the rate-dependent formulation leads to a reduction of the maximum crack speed as compared to a rate-independent model, provided that one takes into account that the elastic layer has finite strength.

REFERENCES

[1] Valoroso, N., Debruyne, G., and Laverne J., A cohesive zone model with rate-sensitivity for fast crack propagation, Mechanics Research Communication, 58:82–87, 2014.

[2] Guimard, J.-M., Allix, O., Pechnik, N., and Thévenet, P., Characterization and modeling of rate effects in the dynamic propagation of mode-II delamination in composite laminates, International Journal of Fracture, 160-1:55–71, 2009.

[3] Ravi-Chandar, K., and Knauss, W.G., An experimental investigation into dynamic fracture - II. Microstructural aspects International Journal of Fracture, 26:65–80, 1984.

[4] Zhou, F., Molinari, J.-F., and Shioya, T., A rate-dependent cohesive model for simulating dynamic crack propagation in brittle materials, Engineering Fracture Mechanics, 72:1383–1410, 2005.

[5] Jirásek, M., and Allix, O., Analysis of self-similar rate-dependent interfacial crack propagation in mode II, submitted to Int. J. of Fracture