Delamination analysis using geometrically non-linear beam finite elements and a rate-dependent cohesive zone model

Leo Škec*, Giulio Alfano† and Gordan Jelenić††

*,† Brunel University London
Kingston Lane, UB8 3PH, Uxbridge, UK
e-mail: {leo.skec;giulio.alfano}@brunel.ac.uk, web page: http://www.brunel.ac.uk

†† University of Rijeka, Faculty of Civil Engineering
Radmile Matejčić 3, 51000 Rijeka, Croatia
e-mail: gordan.jelenic@uniri.hr, web page: http://www.gradri.uniri.hr

ABSTRACT

Layered structures are widely used for optimising functional and structural performance of systems in many engineering applications. Delamination (debonding) between layers is one of the most prevalent and severe failure modes in layered structures. Traditionally, the determination of key parameters governing crack propagation along an interface between layers is based on fracture mechanics, where the critical energy release rate G_c is considered as the most important parameter. Since the value of G_c depends on the mode mixity, specimen dimensions and often on the loading rate, it cannot be considered only as a material or interface property. For the rate-dependent case, the idea of separating out the different dissipation mechanisms occurring during fracture has been a common feature of cohesive zone models (CZMs) recently proposed in [1-3] where the approach is linked to the underlying physics.

CZMs can require a very refined mesh along the potentially delaminating interface, which, in conjunction with 2D and 3D solid elements, has a negative influence on the computational efficiency. The authors of this work developed new computational methods which significantly reduce the total number of degrees of freedom by combining geometrically non-linear beam finite elements for the layers and interface elements with a mixed-mode CZM [4-5]. The formulation showed excellent results and robustness both for small and finite displacements and rotations.

In this work, building on the earlier work [1-5] briefly reviewed above, a rate-dependent mixed-mode interface element is implemented within a multi-layer beam environment. The presented model is verified against experimental results for mode I delamination (DCB test) and computationally more expensive models. The model developed will be a framework for a novel method of determining the material properties of the interconnection of layered structures in conjunction with experimental measurements (e.g. force-displacement diagram for a DCB test).

REFERENCES

[1] M. Musto and G. Alfano, “A novel rate-dependent CZM combining damage and visco-elasticity”, *Comp. Struct,* **118**, 126-133 (2013).
[2] M. Musto and G. Alfano, “A fractional rate-dependent cohesive-zone model”, *Int. J. Num. Meth. Eng*, **105**(5), 313-341 (2015).
[3] G. Alfano and M. Musto, “Thermodynamic derivation and damage evolution for a fractional cohesive-zone model”, Accepted on *J. Eng. Mech.* (2017).
[4] L. Škec, G. Jelenić and N. Lustig, “Mixed-mode delamination in 2D layered beam finite elements”, *Int. J. Num. Meth. Eng,* **104**, 767-788 (2015).
[5] L. Škec and G. Jelenić, “Geometrically non-linear multi-layer beam with interconnection allowing for mixed-mode delamination”, *Eng. Frac. Mech,* **169**, 1-17 (2017).