On the use LEFM, NLFM and CZM in the analysis of a DCB test

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

* †† Faculty of Civil Engineering
University of Rijeka
Radmile Matejčić 3, 51000 Rijeka, Croatia
e-mail: leo.skec@uniri.hr, gordan.jelenic@uniri.hr

† Department of Mechanical and Aerospace Engineering
Brunel University London
Kingston Lane, UB8 3PH, Uxbridge, UK
e-mail: giulio.alfano@brunel.ac.uk

ABSTRACT

Double cantilever beam (DCB) is the standard specimen for determining fracture resistance in mode I. This is usually done by using simple data-reduction schemes that combine linear-elastic fracture mechanics (LEFM) and beam theory (either Euler-Bernoulli or Timoshenko). On the other hand, a richer modelling of the problem through the use of cohesive-zone models (CZMs) is also possible and widely used. This approach, unlike LEFM, allows us to accurately model problems where a relatively large damage process zone (DPZ) develops in front of the crack tip before failure. However, a rigorous study on the relationship between LEFM and CZM seems to be lacking and quantities like the critical energy release rate (G_c), the critical value of the J integral (J_c) used in non-linear fracture mechanics (NLFM) and the area under the traction-separation law of CZM (work of separation) are often misinterpreted.

In our recent work [1, 2], we have shown that, unlike what is often stated in the literature, LEFM can be accurately adopted for DCB problems even in cases with large DPZ (ductile failure). We have demonstrated in a general case, neither G_c nor J_c is equal to the area under the traction-separation law of CZM. Moreover, we have shown that the difference between G_c and J_c, and therefore the applicability of LEFM to problems with quasi-brittle failure, is not due to the size of the DPZ, but it is due to the change of the energy dissipated in front of the crack tip with crack propagation. Additionally, we have proposed a novel data-reduction scheme called 'Enhanced simple beam theory' (ESBT) that is based on Timoshenko beam theory and LEFM, and, unlike all the data-reduction schemes currently used in standards, does not require the measurement of the crack length. Using input data from the numerical model (virtual-experiments), ESBT has proven to be extremely accurate in predicting the input value of the work of separation even for cases with extremely large DPZ.

We have also made a contribution in making the CZM model for DCB extremely fast, accurate and robust in the same time. First, we have shown that, for modelling the arms of a DCB, Timoshenko beam finite elements can be used instead of plane-stress 2D solid finite elements without a noticeable loss in accuracy [2]. Secondly, we have developed a closed-form solution for a DCB with arms modelled as Timoshenko beams and a bi-linear CZM at the interface [3]. This solution, that is completely free of any convergence problems or numerical errors, is also implemented in an open-source software.

REFERENCES

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