

A NOVEL APPROACH FOR THE LOCAL COMPARISON OF THE STRAIN ENERGY RELEASE RATE PREDICTIONS BY VCCT AND CZM

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ABSTRACT

Delamination is a critical failure mechanism of laminated composites, consisting of the separation of two adjacent laminas. This can occur both in the case of static and fatigue loadings. Designing against this failure mode requires the use of advanced numerical tools, the two most common of which are the Virtual Crack Closure Technique (VCCT) and the Cohesive Zone Model (CZM) [1]. VCCT computes the local value of the strain energy release rate G at the delamination front. It is based on linear elastic fracture mechanics, thus preventing any process zone modelling. The technique is known to be mesh dependent because of a discontinuous node-based description of the delamination front. CZM is based on the use of cohesive elements that implement a non-linear traction separation law. These elements can model effectively the process zone ahead of the delamination front, which is described continuously via the elements. Comparison of both approaches can be found in the literature [1-3]; however, all comparisons were performed at the global level, by comparing the load-displacement curve of the simulated structure or specimen. A local comparison of the computed values of G and its decomposition in the different modes was so far not possible because. This was especially true for large and curved fronts, for which the VCCT shows unreliable readings. Therefore, a clear understanding of the real differences and analogies of the two techniques at the local level is still lacking.

In this work, two innovative methods are used together to perform a local comparison of the two approaches. First, a smoothing algorithm is used to allow a more coherent description of the VCCT delamination fronts, thus allowing more reliable and continuous readings of G [4]. Moreover, a recent cohesive elements formulation implementing the J-integral is used to accurately compute the local G in different locations of the process zone [5]. The comparison is thus performed on a non-standard End-Notched Flexure (ENF) specimen, presented in [5] and shown in Fig. 1a. This specimen is characterised by a large and curved delamination front upon loading. To investigate the effect of the process zone in this comparison, two process zone lengths were investigated. The comparison is performed by extracting iso-damage curves in the process zone of the CZM simulation (the dissipated energy w_d is considered as damage [5]); these curves are used as delamination fronts for VCCT simulations. In these simulations, the delamination propagation was prevented by imposing an infinite fracture toughness, so that any value of G could be read. For the exemplificative case of an applied displacement of 28 mm, Figure 1b shows the extracted delamination fronts; Figure 1c shows a comparison between the VCCT and the CZM without the smoothing algorithm for the VCCT simulations, highlighting how this comparison was so far impossible; Figures 1d-f show the comparison for three iso-damage lines. As shown, the predicted trends are similar, but the absolute values often show differences. In addition, the significant differences appear to affect mainly G_{III} , while G_I and G_{II} are more similar: this implies that the total G_{TOT} (the sum of the three components) is also different for the two techniques. A different G_{TOT} necessarily implies a different delamination propagation prediction. These differences are attributed mainly to the presence of the fracture process zone, which thus is critical in controlling the propagation of this delamination case.

Overall, this work first compares the local computation of the strain energy release rate G by VCCT and CZM. The effect of the process zone is also studied by varying the process zone length. Moreover, mode I

DCB simulations with the same non-standard specimen of Figure 1 are also under investigation, thus broadening the range of this study.

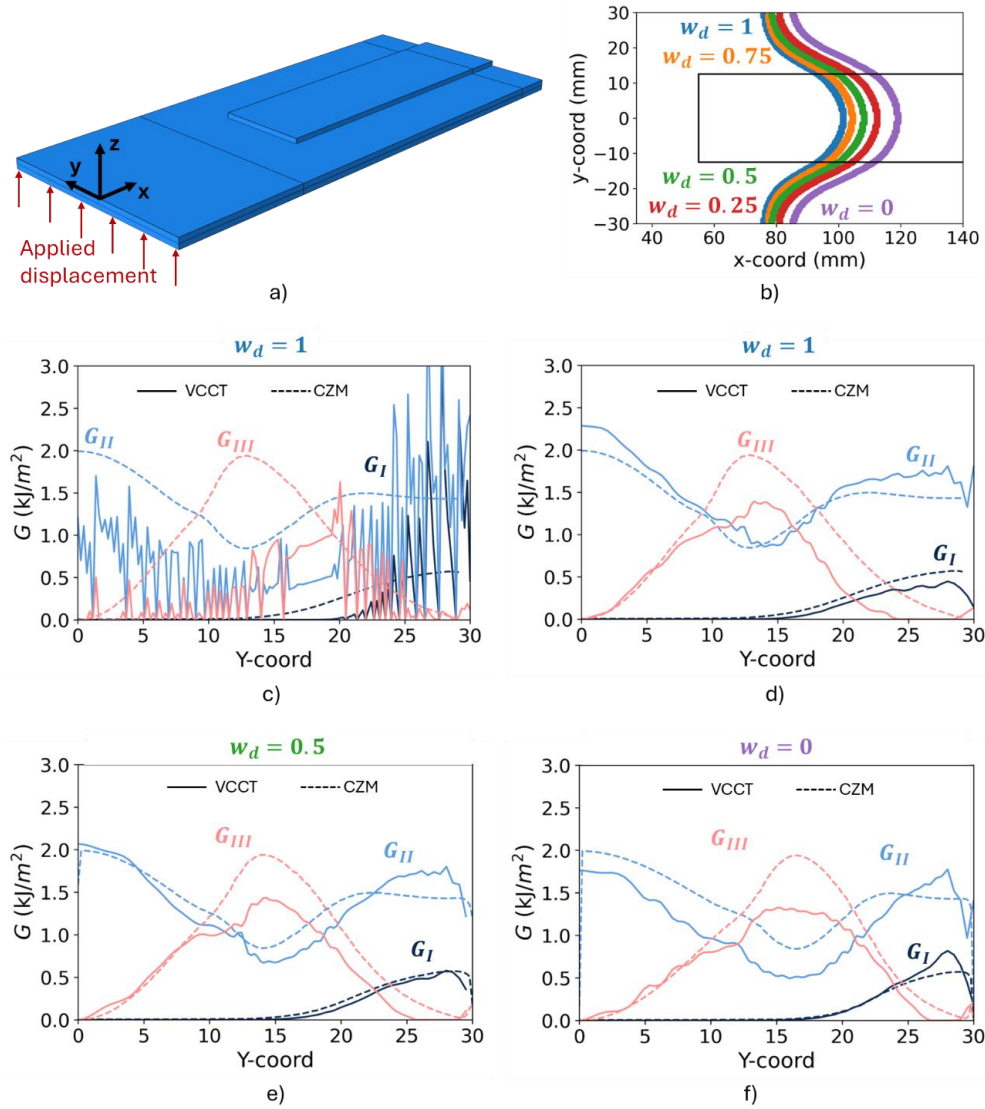


Figure 1: a) the non-standard ENF, b) extracted iso-damage fronts, c) comparison of G with standard delamination fronts for the VCCT simulations, d-f) comparisons of G for the smoothed delamination fronts at different damage w_d .

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