An application of the scaled boundary finite element method to laminates: Prediction of interlaminar crack onset caused by the free-edge effect

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Composite laminates are usually designed preventing failure within individual layers. Beside the so-called intralaminar failure, another failure mechanism in terms of crack initiation between individual layers may occur. This additional failure mode may be triggered by the layer-wise dissimilar stiffness properties yielding highly localized, theoretically infinite, stresses at the bi-material junction along the free edges. The potentially initiated crack may propagate with no obstacles within the thin interlayer which consists of matrix resin and interconnects adjacent individual layers. This yields failure by separation of the layers.

In the present work, interlaminar crack onset induced by the above described so-called free-edge effect is investigated. Due to the singular stress field and the lack of a pre-existing crack neither strength of material approaches, nor fracture mechanics allow for a realistic prediction of interlaminar crack initiation and corresponding failure loads. In contrast, a coupled stress and energy criterion, proposed by Leguillon [1], within the framework of finite fracture mechanics is applied in order to predict the instantaneous formation of a finite sized crack. The underlying mechanical model is conducted according to the work of Pipes and Pagano [2], presuming a generalized plane strain state. Martin et al. [3] already investigated interlaminar crack onset in symmetric angle-ply laminates by means of the coupled stress and energy criterion but the required quantities have been determined using the classical finite element method yielding high computational costs. In the present work instead, the semi-analytical scaled boundary finite element method (SBFEM), introduced by Wolf and Song [4], is used in order to compute the required stress field and energy quantities in an exceptionally efficient manner. The SBFEM has already been successfully used by Sun et al. [5] for the evaluation of the coupled criterion predicting crack onset in notched structures. For validation a classical finite element method is performed additionally.

The obtained results, exhibiting a size effect in terms of the effective failure stress as function of the ply thickness, are in good agreement to experiments from literature and the trends are covered correctly.

References

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