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METHODOLOGY FOR THE SIMULATION OF FATIGUE-DRIVEN DELAMINATION IN 3D COMPOSITE STRUCTURES

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Introduction

Fatigue-driven delamination is one of the most common failure mechanisms in real layered composite structures. A reliable design should account for this damage mechanism. Recently, Bak et al. [1] presented a method based on a cohesive zone model approach which does not rely on any fitting parameter. However, due to the lack of applicable formulations of the *J*-integral in 3D cohesive interfaces, Mode III was disregarded and the model was only validated in 2D.

In this work, the method is enhanced for its application to 3D structures were the crack front shape can change during fatigue propagation.

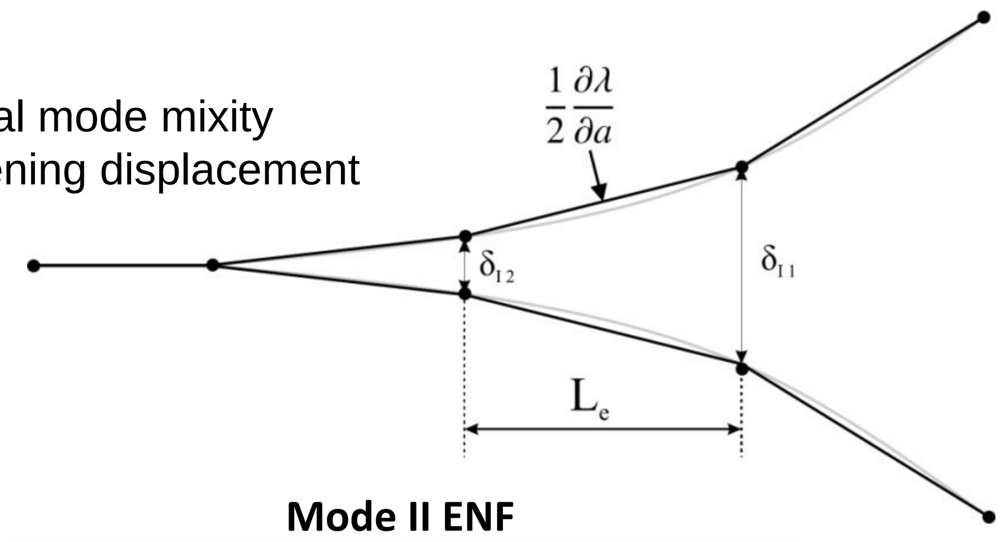
Method for high-cycle fatigue-driven delamination using a cohesive zone model

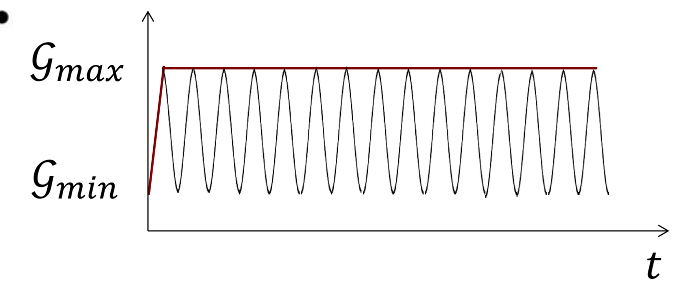
The method presented in [1] directly links the cohesive zone model approach for quasi-static crack propagation with any variant of the Paris' law describing the crack growth rate.

$$\frac{dD}{dN} = \left(F_\beta \frac{\partial \beta}{\partial a} + F_\lambda \frac{\partial \lambda}{\partial a}\right)\frac{da}{dN}$$

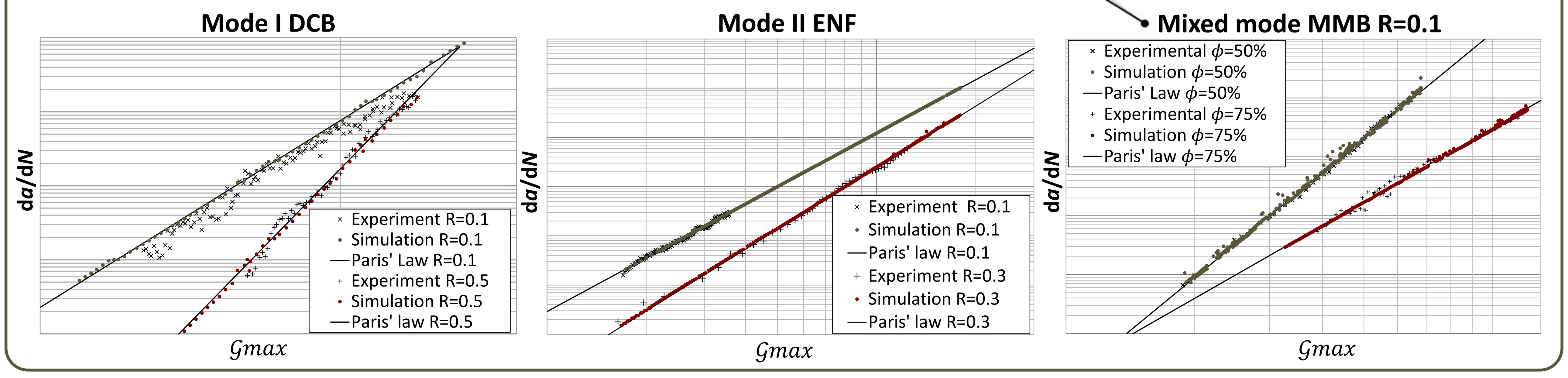
β: local mode mixity
λ: opening displacement

$$\frac{da}{dN} = f(\mathcal{G}_{max}, R, \phi) \qquad \phi = \frac{\mathcal{G}_{II}}{\mathcal{G}_I + \mathcal{G}_{II}}$$





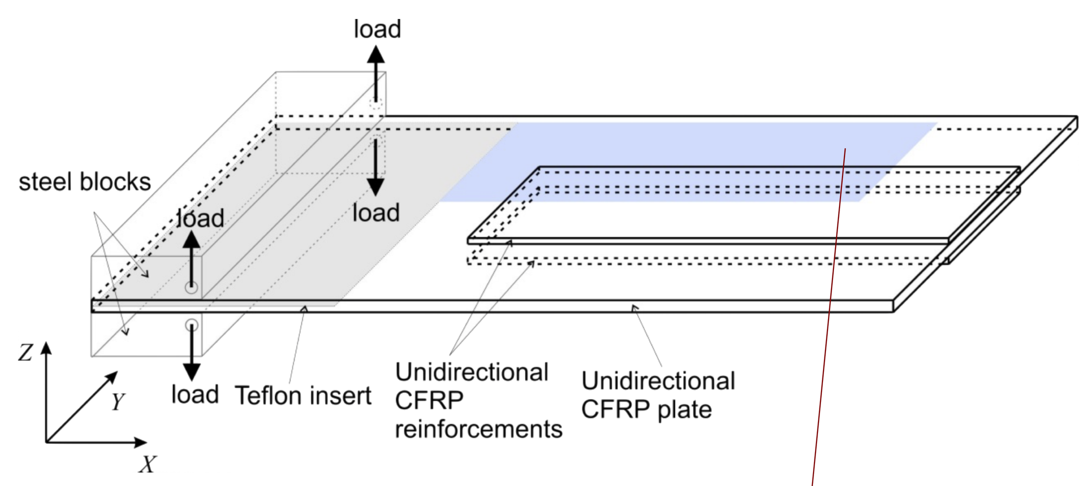
$$R^2 = \frac{\mathcal{G}_{min}}{\mathcal{G}_{max}}$$

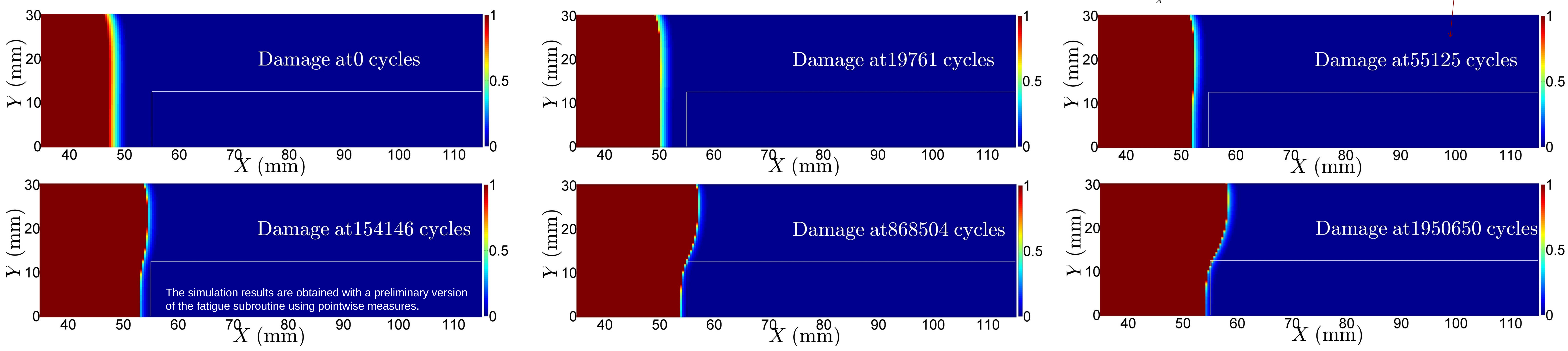


Extension of the method for 3D application

The *J*-integral is used in [1] to determine the mode I and shear components of the energy release rate that feed the Paris' law. The computation of this value requires the proper identification of the crack propagation direction within the cohesive zone which, in **a 3D structure**, is not straightforwardly deduced. Moreover, the evaluation of the damage rate also requires the **crack propagation direction** to compute the opening displacement and local mixed-mode ratio slopes along the crack growth coordinate, $\frac{\partial \lambda}{\partial a}$ and $\frac{\partial \beta}{\partial a}$ respectively.

These two challenges have been solved with the **pointwise description of the crack front shape** and the **mode-decomposed *J*-integral** presented in *Evaluation of the decomposed J-integral in 3D crack fronts using cohesive elements* – **PO 43** (COMPTEST2017).





A symmetric run-out specimen with a midplane initial defect has been simulated. The damage state after different number of applied cycles is shown in the Figure. The model inherently captures the change on the crack front shape and on the width of the process zone during fatigue propagation. For the geometry and boundary conditions simulated, crack arrest is predicted when the crack reaches the stiffener.

Conclusions

A model to simulate fatigue in 3D structures is presented. Two new developments have been introduced: a local crack propagation direction criterion and a 3D expression for the mode decomposed *J*-integral. The formulation predicts the crack front shape merely using information available at element level. The method has been implemented in a Finite Element framework. The model predicts crack front shape changes during fatigue growth in 3D structures. The model can be used to predict delamination onset and growth in complex aeronautical components.

References

[1] Bak BLV, Turon A, Lindgaard E, Lund E, *A Simulation Method for High-Cycle Fatigue-Driven Delamination Using a Cohesive Zone Model*, International Journal for Numerical Methods in Engineering, **106**, 2016, p. 163-191.

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