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FATIGUE COHESIVE ZONE MODELLING OF A BENCHMARK TEST FOR COMPOSITES UNDER COMPLEX LOADING SEQUENCES RESULTING IN NON-SELF-SIMILAR DAMAGE EVOLUTION

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ABSTRACT

To reduce costs during the certification processes, it is of great interest to substitute some of the upper part of the testing pyramid by analysis methods and simulation strategies such as virtual testing [1]. For that propose, predictive tools must be capable of accurately modelling the failure mechanisms.

Cohesive zone models (CZM) are widely used to simulate fracture and damage evolution in composite materials under different loading modes, monotonic, and fatigue loading. However, some models are not able to simulate 3D structures or transient states of damage evolution caused by in-service loading conditions [2]. Most of the state-of-the-art fatigue CZM accumulate fatigue damage based on Paris´ law equations. This implies that a) fatigue onset response is not correlated with experimental data and b) if the fatigue crack growth behaviour of the material is influenced by its resistance curve (R-curve), or if there are transitional effects on damage evolution, specific experimental data regarding the crack growth law in non-fully developed regimes should be provided. [3].

Alternatively, Dávila *et al*. developed a local CZM inspired on S-N curves [4] that links the damage rate dD/dN to the static cohesive law. Additionally, a simulation strategy was proposed in [5] to determine the model parameters and accumulate fatigue damage in multiples superposed cohesive laws, allowing accurate modelling of fatigue onset and propagation considering R-curve effects.

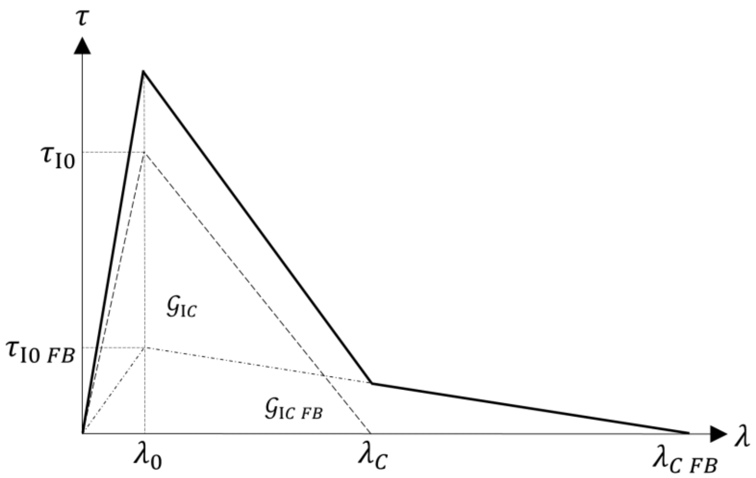

Figure 1: Superposition of cohesive laws to model R-curve effects.

In this work, the fatigue CZM developed in [4] and the simulation strategy proposed in [5] are adopted to simulate a novel fracture benchmark test that is considered as equivalent of in-service loading since it considers the transient effects of alternating different loading modes, monotonic, and fatigue loading. The case study was performed on a AS4D/PEKK-FC thermoplastic composite. Different combinations of loading modes, monotonic, and fatigue loading were applied. The non-self-similar damage evolution of different failure mechanisms such as brittle fracture, plastic deformation, and large-scale fibre bridging were correlated qualitatively to the different superposed cohesive laws, giving an insight on the phenomenological nature of superposing cohesive laws.

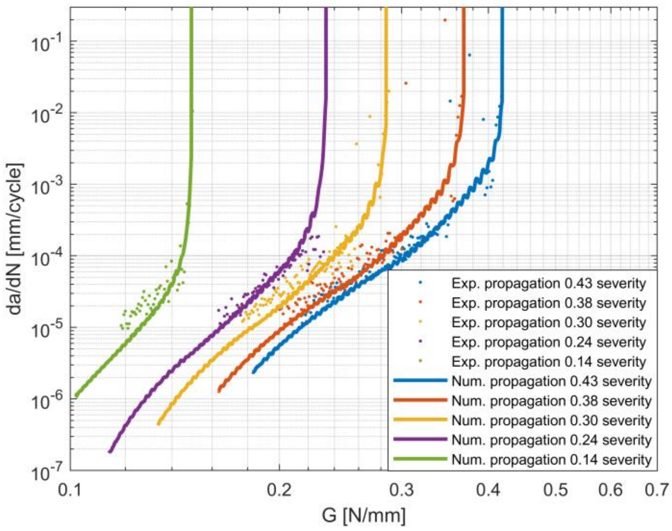

Figure 2: Modelling of fatigue R-curve effects.

REFERENCES

[1] B. H. A. H. Tijs *et al.*, "Virtual testing of thermoplastic composites: Towards a hybrid simulation-physical testing pyramid," *ECCM 2018 - 18th Eur. Conf. Compos. Mater.*, 2018.

[2] B. L. V Bak, A. Turon, E. Lindgaard, and E. Lund, "A Benchmark Study of Simulation Methods for High-Cycle Fatigue-Driven Delamination Based on Cohesive Zone Models," *Compos. Struct.*, 2016, doi: 10.1016/j.compstruct.2016.11.081.

[3] L. Carreras *et al.*, "A simulation method for fatigue-driven delamination in layered structures involving non-negligible fracture process zones and arbitrarily shaped crack fronts," *Compos. Part A Appl. Sci. Manuf.*, vol. 122, no. January, pp. 107–119, 2019, doi: 10.1016/j.compositesa.2019.04.026.

[4] C. G. Dávila, C. A. Rose, G. B. Murri, W. C. Jackson, and W. M. Johnston, "Evaluation of fatigue damage accumulation functions for delamination initiation and propagation," *Nasa/Tp–2020-220584*, no. April, 2020.

[5] I. Lecinana, J. Renart, A. Turon, J. Zurbitu, and B. H. A. H. Tijs, "Characterization and analysis of the mode I interlaminar fatigue behaviour of thermoplastic composites considering R-curve effects," *Submited*, 2023.