11th International Conference on Composites Testing and Model Identification
J. Costa, J. Renart and N. Blanco (Editors)
Girona, 2023

A NOVEL BENCHMARK TEST FOR COMPOSITES UNDER COMPLEX LOADING SEQUENCES RESULTING IN NON-SELF-SIMILAR DAMAGE EVOLUTION

Jordi Renart[1], Laura Carreras[1], Iñaki Leciñana[1,2], Javier Zurbitu[2], and Albert Turon[1]

[1]AMADE Research Group
Polytechnic School, University of Girona, Campus Montilivi s/n, E-17003 Girona, Spain
Email: jordi.renart@udg.edu, web page: http://amade.udg.edu/

[2] IKERLAN Technology Research Centre, Basque Research and Technology Alliance (BRTA), Po.J.Ma. Arizmendiarrieta 2, 20500 Arrasate-Mondragon, Gipuzkoa, Spain
Email: ilecinana@ikerlan.es, web page: https://www.ikerlan.es/

Keywords: Benchmark test, Fracture, Damage evolution, X-ray Tomography

ABSTRACT

Transport industry is increasingly moving towards more optimized and lightweight structures. Cost-efficient and sustainable designs must meet structural integrity and reliability. Experimental testing is the basis in which state of the art design tools are developed, providing material properties and validation data to those tools.

Monotonic, fatigue, and durability characterization methodologies under different loading modes in composite materials have been widely studied in literature over the past decades [1]–[3]. Characterization tests are usually performed in geometrically simple specimens, and data reduction schemes are used trying to synthesize the whole experiment into some experimental constants, assuming that they are representative of a material property. However, some simplifications which are not representative of the in-service loading conditions are sometimes made. Among others, the transient the effects of alternating different loading modes, monotonic, and fatigue loading is not considered in characterization tests. Moreover, in fracture characterization tests, self-similar damage evolution is generally assumed, collapsing the whole fracture process zone with linear elastic fracture mechanics approaches.

Sometimes, characterization tests are taken as a reference to validate predictive models [4]. This practice may result in not considering some important effects that are present in-service. In this work, a novel fracture benchmark test that quantifies the transient effects of alternating different loading modes, monotonic, and fatigue loading is presented. Moreover, it does not just give information from the crack tip location, it also gives qualitative information of the fracture process zone evolution using X-ray tomography data. The benchmark test is based on the double cantilever beam concept, but some modifications were made to achieve non-self-similar damage evolution.

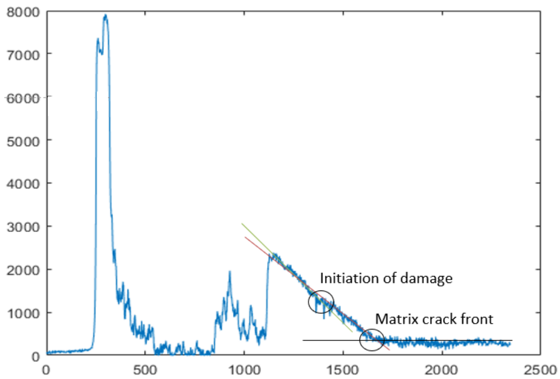

Figure 1: Post-processing of X-ray tomography.

To demonstrate the capabilities of the benchmark test, a case study was performed on a AS4D/PEKK-FC thermoplastic composite. Different combinations of loading modes, monotonic, and fatigue loading were applied. Load-displacement, X-ray tomography, and fractography data was obtained and correlated, being able to monitor the non-self-similar damage evolution of different failure mechanisms as brittle fracture, plastic deformation, and large-scale fibre bridging. The results may be used as reference to validate predictive models that deal with monotonic damage, fatigue damage and fracture. It also provides new information for understanding the mechanics underlying the fracture processes.

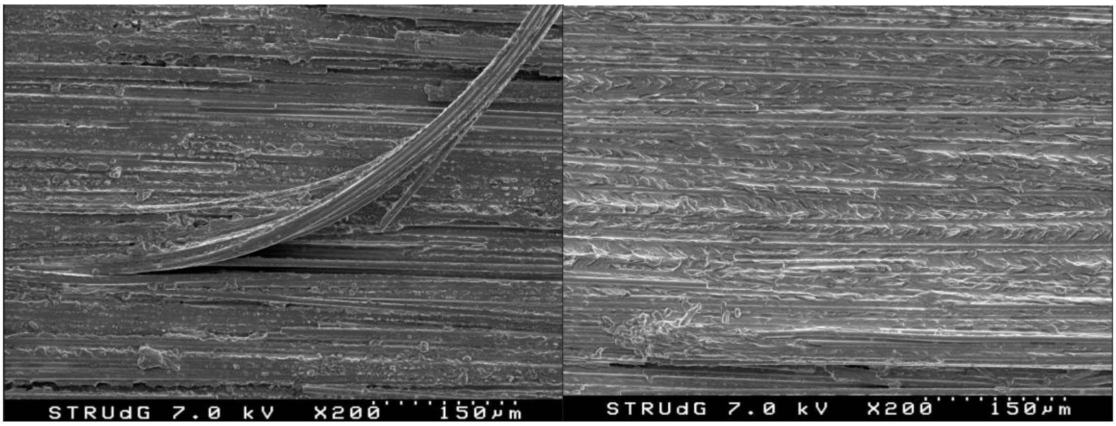

Figure 2: Traces of different failure mechanisms present in the fracture surfaces: a) Fibre bridging and b) plastic deformation.

REFERENCES

[1] B. L. V Bak, C. Sarrado, A. Turon, and J. Costa, "Delamination Under Fatigue Loads in Composite Laminates : A Review on the Observed Phenomenology and Computational Methods," *Appl. Mech. Rev.*, vol. 66, no. 6, 2014, doi: 10.1115/1.4027647.

[2] R. C. Alderliesten, A. J. Brunner, and J. A. Pascoe, "Cyclic fatigue fracture of composites: What has testing revealed about the physics of the processes so far?," *Eng. Fract. Mech.*, vol. 203, no. June, pp. 186–196, 2018, doi: 10.1016/j.engfracmech.2018.06.023.

[3] M. Pérez-Galmés, J. Renart, C. Sarrado, A. J. Brunner, and A. Rodríguez-Bellido, "Towards a consensus on mode II adhesive fracture testing: Experimental study," *Theor. Appl. Fract. Mech.*, vol. 98, pp. 210–219, 2018, doi: 10.1016/j.tafmec.2018.09.014.

[4] 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.