Capturing the Off-axis Response of Thin-ply Laminates

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The ability to simulate the response and obtain accurate strength predictions for multidirectional laminated composite components is of prominent interest in the aeronautical field, especially concerning notched components, which often appear in aeronautical structures (e.g., bolted, riveted sheets). In this work, focus is attributed to a novel composite system, thin-ply laminates (i.e., plies of thicknesses under 0.1 mm) that have been shown in the literature to present different fracture patterns compared to *"standard"* ones (i.e., plies of thicknesses over 0.1 mm). In the former case, final failure tends to happen in the form of a single fracture plane. This motivates the use of the phase field method (PF), nominally used for brittle fracture, following an equivalent single layer (ESL) representation for the composite laminated plate.

The feasibility and application of this method is evaluated on the basis of off-axis (i.e., referring to loading on a direction that does not coincide with one of the principal axes of orthotropy of the plate) open-hole tension of a multidirectional laminate based on the experimental results of [1]. Results obtained using the anisotropic PF model of [2], which uses a 2nd order structural tensor to account for anisotropic fracture energy, reformulated as in [3] to include specific considerations of the toughness of a composite laminate, are initially presented. A successful prediction of the experimental results both with regards to fracture plane (Fig. 1) and strength, with a maximum observed error in predicted strength of 4.8%, is achieved.

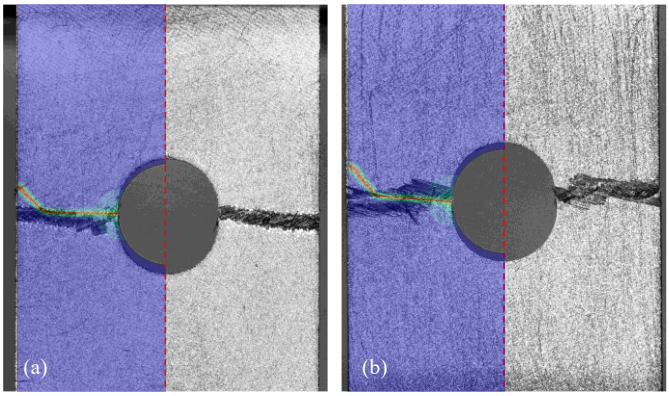

Fig.1 – Comparison of experimental and numerical crack paths for (a) 30º off-axis loading and (b) 60º off-axis loading.

References

[1] C. Furtado, R. P. Tavares, A. Arteiro, J. Xavier, P. Linde, B. L. Wardle, P. P. Camanho, Effects of ply thickness and architecture on the strength of composite sub-structures, Composite Structures (2021), 256, 113061.

[2] S. Teichtmeister, D. Kienle, F. Aldakheel, M. A. Keip, Phase field modeling of fracture in anisotropic brittle solids, International Journal of Non-Linear Mechanics (2017), 97: 1–21.

[3] A. Mitrou, A. Arteiro, J. Reinoso, Modeling fracture of multidirectional thin-ply laminates using an anisotropic phase field formulation at the macro-scale. *under review (2022)*