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EVALUATING THE INTRALAMINAR TENSILE FRACTURE BEHAVIOR OF COMPOSITE MATERIALS UNDER HIGH RATE LOADING THROUGH A COMBINED EXPERIMENTAL AND NUMERICAL METHODOLOGY

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ABSTRACT

The behavior of composite materials under dynamic loading conditions has been a topic of research for the past two decades. When subjected to dynamic conditions, such as high-strain-rate loading, composite materials exhibit significant strain rate sensitivity. This could be critical when it comes to selecting appropriate material properties and model for dynamic loading cases.

To understand this sensitivity, researchers have proposed several experimental methodologies. One of the most widely used methods is the Split Hopkinson Pressure Bars (SHPB) method [1], which is particularly useful for evaluating the dynamic behavior of materials in the strain rate range representative of an impact (50-1000s-1).

Most research in this field has been focused on the determination of the variation of mechanical properties in this range of strain rate loadings, including properties of individual constituents, failure mechanisms, and fracture toughness for both intralaminar and interlaminar behavior. However, there have been only a few studies concerning fracture toughness analysis, which is a measure of a material's resistance to crack growth. The study by et al. [2] was one of the first to investigate this aspect in composite materials, but the data reduction method used in this study can be improved by including the strain rate dependence of elastic properties in the material model. More recent studies, such as the work of Hoffmann et al. [3] (using the Compact Tension specimen) and the work of P. Kuhn et al. [4] (using the double edge notched tensile specimen), have reported divergent conclusions for the same material, indicating that the optimal technique for characterizing this property under high-rate loading is still unresolved.

To address this issue, a combined experimental-numerical methodology has been proposed to determine the cohesive law of the Mode I intralaminar failure mode under dynamic loadings. This methodology is based on the work of C. Dávila et al. [5]. SHPB tests were conducted using the original geometry of the Compact Tension specimen based on the work of Hoffmann et al. [3]. An efficient numerical model was implemented in ABAQUS/Explicit, where shell elements and cohesive elements were used to reproduce the specimen's behavior. An iterative process was then conducted to match the force-opening curve of the experimental tests and define the appropriate cohesive law. The process was validated with the quasistatic test campaign, while the dynamic test provided the strain rate effects for the cohesive law. The proposed methodology overcomes inconveniences of previous

methodologies such us the use of a set of different geometries or the measuring of the crack propagation during the test.

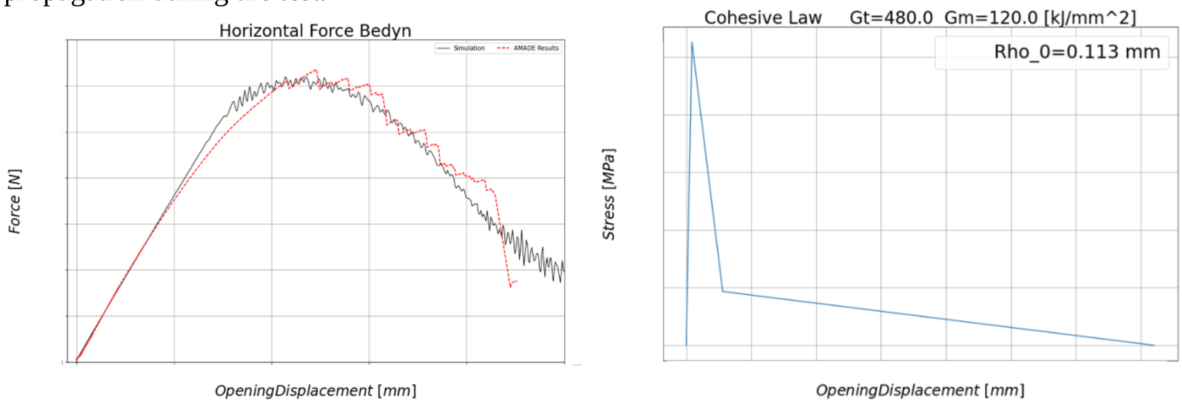

Figure 1: Left: Experimental and numerical Force-Opening displacement curve for a CT test. Right: Cohesive Law used for the numerical model

This work has been conducted within the framework of the European Clean Sky project “BEDYN - Development of a methodology (test, measurement, analysis) to characterize the behavior of composite structures under dynamic loading (GA. 886519)”. This project aims to define a complete methodology for characterizing composite materials under dynamic loadings by including the definition of well-suited experimental tests at the coupon level.

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