Progressive Failure in Composite Laminated Panels: Experiments, Analysis and Modeling

Anthony M. Waas
Professor of Aerospace Engineering and Mechanical Engineering,
University of Michigan,
Ann Arbor, MI 48109-2140

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A large body of literature devoted to progressive failure analysis (PFA) of composite laminated structures is now present. Many of the PFA schemes introduced and available today have relied on the phenomenological approach of defining strength criteria for a single lamina when subjected to different single component stress states. These methods define the onset of failure through specific indices that are expressed as functions of the current stress state. When any of these indices exceeds a predefined critical value, the material at that point is said to have failed. When a material point has failed, for subsequent loading, it is assumed to have a reduced stiffness that is predetermined in an empirical manner. Depending on the type of failure (for instance, fiber breaking and/or matrix cracking due to tension along the fibers, fiber kink-banding due to compression along the fibers, fiber/matrix debonding due to in-plane shear), different elastic moduli are either set to zero or degraded in a pre-defined manner.. In addition, linear elastic material behavior is assumed throughout the analysis. In a laminated composite plate, the stiffness at a material point is determined by the current local stress state and the local `state' of the material. The local stress state, in general, is multi-axial and a material point at the current state may have accumulated damage, dictated by the past loading history. Thus, `strength' at a material point is influenced to a great extent by the current stress and strain state and further, is predicated on the mechanism of failure. PFA methodologies that abruptly change material properties based on strength `indices' and rely on a linear elastic analysis may be unable to realistically account for features associated with the mechanisms of failure. For progressive failure modeling, a framework that accounts for the continued degradation of the material may be needed. In addition, different failure modes (for example, delamination and fiber kinking) may be simulataneously present in the regime of continued progressive failure and this framework should be able to account for the interaction between different failure modes. The results obtained from these latter PFA schemes (mechanism dependent failure modeling) will be summarized in this talk. Experimental, Analytical and Numerical approaches to PFA will be discussed and outstanding issues that concern interaction of failure modes and strategies to account for these will also be discussed.