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DAMAGE INSTABILITY AND TRANSITION FROM QUASI-STATIC TO DYNAMIC FRACTURE

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Summary: The typical structural test performed during the detail design of a composite airframe consists of two main phases. The initial response is quasi-static and elastic (linear or not). The quasi-static loading phase often continues even after cracking sounds begin to occur. As the loading approaches the ultimate strength of the structure, the acoustic emissions usually intensify until the structure violently collapses. This unstable collapse, referred to as a snapback response, is inherently dynamic. It is only after this dynamic event takes place that the strength and modes of failure can be evaluated. The load-carrying capability of the structure corresponds to the intersection of the quasi-static and the dynamic phases of the response.

Predicting structural strength presents a number of difficulties. First, the analysis method best suited for quasi-static structural analyses is the implicit finite element method, while the explicit direct integration is best used to represent highly dynamic responses. The quasi-static loading phase defines the damage and stress distributions that cause the loss of stability of the structure, and the collapse is the process that creates the morphology of the fracture. Therefore, both phases of the response are needed. For an accurate prediction, it is therefore essential to use tools and methodologies that are capable of capturing the state of the structure and the material at the point of instability and afterwards.

However, when implicit methods are applied to problems with material softening, the load incrementation procedure often fails to converge. These numerical difficulties start with the appearance of negative eigenvalues that do not provide much useful information to the user, and the difficulties continue as the solver attempts to reach an equilibrium solution by cutting the load increment to increasingly small values. In the end, the load incrementation procedure stops due to divergence of the solution or due to a minimum load increment having been reached.

In this presentation, we examine different aspects of the fracture process that must be represented correctly to obtain accurate strength predictions. In particular, the importance of accounting for the load redistribution through proper material softening and the role such redistributions play on scale effects and notch sensitivity are considered. Finally, the effects of R-curve fracture response on the instability of damage propagation is examined, and the use of implicit dynamics and damage-based arc-length load incrementation methods to obtain unstable equilibrium solutions are discussed.