

Residual Strength of Thin Panels with Cracks

by

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The previous design philosophies involving safe life, fail-safe and damage tolerance concepts become inadequate for assuring the safety of aging aircraft structures. For example, the failure mechanism for the Aloha Airline accident involved the coalescence of undetected small cracks at the rivet holes causing a section of the fuselage to peel open during flight. Therefore, the fuselage structure should be designed to have sufficient residual strength under worst case crack configurations and in-flight load conditions. Residual strength is interpreted as the maximum load carrying capacity prior to unstable crack growth.

Internal pressure and bending moment constitute the two major components of the external loads on the fuselage section during flight. Although the stiffeners in the form of stringers, frames and tear straps sustain part of the external loads, the significant portion of the load is taken up by the skin. In the presence of a large crack in the skin, the crack lips bulge out with considerable yielding; thus, the geometric and material nonlinearities must be included in the analysis for predicting residual strength. Also, these nonlinearities do not permit the decoupling of in-plane and out-of-plane bending deformations.

The failure criterion combining the concepts of absorbed specific energy and strain energy density addresses the aforementioned concerns. The critical absorbed specific energy (local toughness) for the material is determined from the global specimen response and deformation geometry based on the uniaxial tensile test data and detailed finite element modeling of the specimen response. The use of the local toughness and stress-strain response at the continuum level eliminates the size effect. With this critical parameter and stress-strain response, the finite element analysis of the component by using STAGS along with the application of this failure criterion provides the stable crack growth calculations for residual strength predictions.